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Teaching ASL Fingerspelling to Second-language Learners: Explicit Versus Implicit Phonetic Training

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Teaching ASL Fingerspelling to Second-language Learners: Explicit Versus Implicit Phonetic Training

by

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For Cecilia and Virginia.

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Abstract

Teaching ASL Fingerspelling to Second-language Learners: Explicit Versus Implicit Phonetic Training

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This dissertation explores the use of explicit phonetic instruction to students acquiring a second language (L2) in a new modality. Studies of spoken language L2 teaching have shown that learners can be trained to attend to phonetic cues in their new language and that explicit training is the most effective means by which to achieve this. Second-language learners of American Sign Language (ASL) struggle with fingerspelling comprehension more than many other aspects of language-learning; previous work has suggested that part of this challenge is due to the inability to observe and make use of phonetic cues present in the fingerspelling stream. The goal of this dissertation is to determine whether explicit training can benefit ASL learners for fingerspelling comprehension tasks.

Two studies assessed an explicit phonetic training program for ASL learners. An implicit fingerspelling training based on a popular ASL curriculum was also developed and used as a control with which to compare the effect of the explicit training. Designed based on a combination of interactions with L2 students in the classroom, descriptions of coarticulatory features in fingerspelling production, and studies of cues L2 students use to comprehend fingerspelling, the explicit training consisted of two main portions. The first detailed the properties of hold versus transition segments in fingerspelling; the second focused on phonetic variation in fingerspelling production.

The first study involved 18 third-semester ASL students in a five-week summer session. The second involved 80 students taking ASL III in a 15-week fall semester. In both studies, students were divided into two balanced groups based on grades earned in their previous ASL course. One group received the explicit training and the other, the implicit fingerspelling training. Pre- and post-tests involved a fingerspelling comprehension task with two experimental conditions and a control condition. In one condition, periods in which signers hold a letter posture were masked (transitions-only), and in the other condition, periods of transition from posture to posture were masked (holds-only).

Results from the first study revealed a strong effect of the explicit training across experimental conditions, though participants struggle most with the transitions-only condition. Results from the second study revealed a weaker overall effect of the explicit training, but a stronger interaction with the transitions-only condition, which the explicit training helped to address specifically. Taken together, results from both experiments reveal that explicit instruction is more effective in improving students' fingerspelling comprehension scores. These effects are not ephemeral. With only one exposure to the training program, which lasts approximately 30 minutes, higher scores persist three and six weeks post training.

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Chapter 1

Introduction

Fingerspelling, or spelling on the hands using manual letters, is a process used in some signed languages to represent written words in the manual modality. In American Sign Language (ASL), one-handed manual letters represent the characters in the English alphabet, while some other signed languages – British and Turkish are two examples – use two-handed systems. The ASL manual alphabet is presented in Figure 1.1. At first blush, it may be tempting to characterize ASL fingerspelling as having 26 distinct handshapes, just as the English alphabet has 26 characters. More careful inspection, however, reveals that several representations of orthographic characters actually share handshapes and so must be distinguished in some other way. For example, the letter pairs -G- and -Q-, -H- and -U-, and -K- and -P- share a handshape but are distinguished by different orientations of the palm. Both -I- and -J- begin identically, but the latter traces the shape of the letter *j*, resulting in a change in the palm orientation. Given these facts, it is more accurate to say that English orthographic characters are represented by a unique combination of handshape and orientation of the palm. They are then produced in rapid sequence to form words.

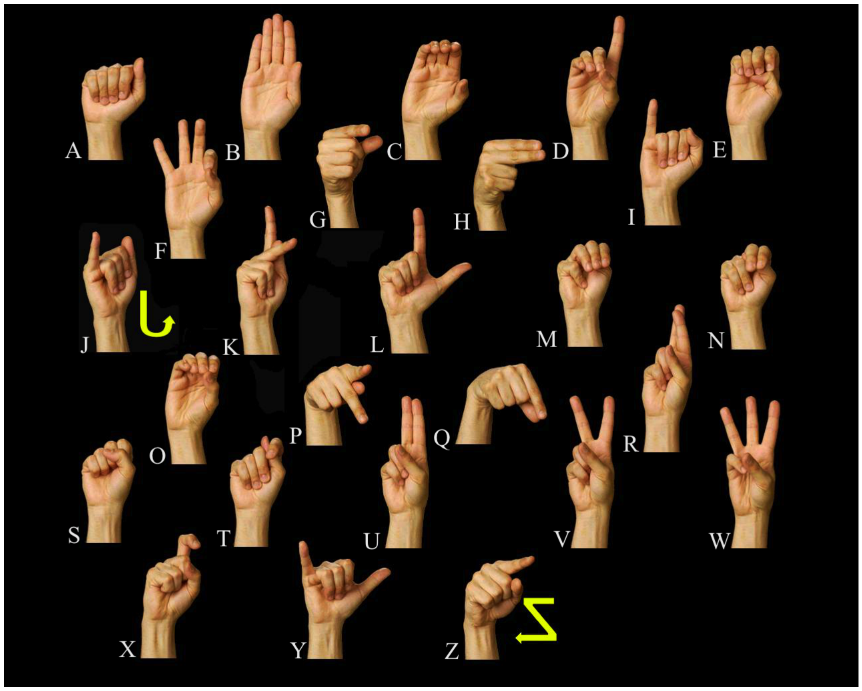


Figure 1.1: Chart of the manual alphabet in ASL.

There are many compelling reasons which make fingerspelling an appealing area of study that can have implications for various linguistic disciplines: phonology, typology, processing, and second language acquisition, to name a few. Here are several more specific reasons fingerspelling is worthy of investigation.

1. Fingerspelling occurs frequently in ASL; estimates range from 10-20% of signed texts, depending on the signer and content of the text (Morford and MacFarlane, 2003; Padden and Gunsauls, 2003).

2. Fingerspelling requires highly dexterous and temporally controlled movements, which can make it difficult to acquire and difficult to perceive.

3. Fingerspelling may be acquired in fundamentally different ways by native/early signers and those who learn ASL after developing literacy skills (Padden, 2006). This is due, in part, to the different cognitive abilities and knowledge of English that learners of different ages bring to the task. There also may be differences in how children versus adults parse the fingerspelling input stream, which has been suggested for linguistic input generally (Morgan et al., 1987). This suggests that age of acquisition may have a profound impact on fingerspelling production (see Geer, 2013, for one such study of differences in fingerspelling in native versus non-native signers), which in turn can affect fingerspelling comprehension.

4. Fingerspelling has handshape distinctions not made in the core vocabulary, excluding classifiers (Brentari and Padden, 2001). *Core* can be taken to mean either the "native" vocabulary of ASL (Padden, 1998) or the semantically basic vocabulary of any language.

5. Different fingerspelling systems impact the core lexicon in different ways, which makes the vocabularies of signed languages, some of which may be fairly similar otherwise, distinct.

6. Fingerspelling is interesting because it is organized sequentially unlike lexical signs, which are organized simultaneously.

7. Adult learners, predominantly native speakers of American English, struggle with this aspect of L2 ASL language acquisition more than other aspects of language acquisition (Quinto-Pozos, 2011; Wilcox, 1992).

Reasons 4, 5, 6, and 7 deserve more explication. There are two important points to discuss with respect to the handshape distinctions in fingerspelling (number

4). Not only are there more handshapes used in fingerspelling than in the core lexicon, these distinctions are used with greater frequency. Within the core, around 50% of signs involve use of the same four handshapes (Henner et al., 2013), a trend evidenced in other signed languages as well (Johnston and Schembri, 2007, for Auslan; Mann et al., 2010, for BSL; Karnopp, 2002, for Brazilian Sign Language; and Ann, 2005, for Taiwanese Sign Language). The same set of basic unmarked handshapes is evidenced across these languages. Given this, the number of distinct handshapes used in fingerspelling may set it apart from the rest of the lexicon with respect to how it is processed and how learners come to understand it.

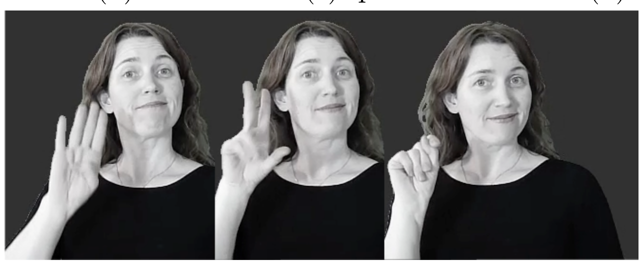
Regarding number 5, languages use their fingerspelling systems in various ways, including the formation of signs via lexicalization of fingerspelling and initialization. Lexicalization is a process by which items enter the lexicon through extensive phonological restructuring of words that were originally borrowed from English via fingerspelling. There are many examples of this in ASL including the signs BUS, BUT, and EARLY. Initialization is a word-formation process by which a sign's handshape specification is that of the representation of the first letter of the English (or majority language) word. For example, the ASL signs CLASS, GROUP and TEAM are formed by tracing the outline of a sphere with both hands in neutral space in front of the signer with the handshapes -C-, -G-, and -T-, respectively. Figure 1.2 presents several additional examples of lexicalized fingerspelling and initialization from three languages. Each of the items presented is part of the basic vocabulary of these languages. An additional example comes from the signed language used in Quebec (Langue des signes québécoise, or LSQ). ASL and LSQ are both historically related to French Sign Language, still share many lexical items, and remain in contact with one another in certain areas of Canada. One core lexical item that differs is that of the *wh-* sign for 'where'. The ASL sign is produced with an extended index finger wagging back and forth in neutral space, while the LSQ sign is a lexicalized form of the fingerspelled French word for 'where', *ou*.

(a) 'MOTHER'

(b) 'FATHER'

(c) 'þRIÐUDAGUR'

(d) 'GREEN'



(e) 'BUT'

Figure 1.2: Items (a) and (b) are made with the British Sign Language handshapes -M- and -F-, respectively, tapped on the non-dominant hand. Item (c) is from Icelandic Sign Language. It is an initialized sign meaning 'Tuesday,' formed with the 'þ' handshape. Image (d) is made with the ASL -G- handshape. Image (e) is an example of a lexicalized fingerspelling sign in ASL. The letters -B- and -T- are produced close to their citation form; however the -U- is made in transition between the two. The letter -U-'s citation form is undershot in this still image; the pinky and ring fingers are flexing after having been extended in the letter -B- and the index and middle fingers are spread as they prepare for the insertion of the thumb for the letter -T-. Examples (a)-(d) were extracted from `https://www.spreadthesign.com`. To view these videos, go to this website and type the sign's English translation equivalent then click on the correct country's flag. Example (e) was extracted from `http://www.handspeak.com/word/search/index.php?id=290`.

As reason 6 indicates, fingerspelling is structured differently than lexical signs. This has implications for processing. Lexical signs make use of simultaneous layering of linguistic features, rather than the sequentiality observed in the structure of spoken languages (Klima and Bellugi, 1979; Brentari, 2002). This different structure is relevant for two reasons. First, the simultaneous layering of linguistic information makes it possible to express propositions in signed languages at rates comparable to those of spoken languages even though the rate of sign production in ASL is much slower, around 2.3 signs per second (Bellugi and Fischer, 1972; Hwang, 2011), than word production in English. Second, the structure of words and signs is related to the sensory system primarily responsible for processing that type of input. Vertical processing refers to the ability to perceive cues presented simultaneously and horizontal processing refers to the ability to process sequentially ordered information. Both vertical and horizontal processing are used in vision and audition (Bregman, 1990), but which processing system is most dominant depends on the signal type. Generally speaking, vision better handles tasks that involve layering of information (Hirsch and Sherrick, 1961; Green, 1971; Welch and Warren, 1986; Kohlrausch et al., 1992; Chase and Jenner, 1993; Meier, 1993; Brentari, 2002), while audition is better suited to processing tasks in which information is organized sequentially. What makes fingerspelling interesting, then, is that despite the modality's general preference for vertical organization, fingerspelling is sequentially, or horizontally organized. This means that fingerspelling is potentially more difficult to perceive not only because it has different handshape distinctions than the core lexicon but also because the visual system may not be optimally suited to processing information organized in this way.

Because of this conflict between how lexical signs are organized and perceived versus how fingerspelling is organized and perceived, examinations of how learners acquire fingerspelling comprehension skills may inform studies of second language acquisition more generally. It might be predicted that second-language learners should be better at fingerspelling than other aspects of ASL acquisition because it is more closely related to English and it is sequentially organized like the type of linguistic information they are used to processing. On the other hand, fingerspelling is also very unlike the rest of the sign lexicon.

Finally, number 7 is the most pedagogically relevant reason to investigate fingerspelling as a window into second language acquisition. As researchers have noted, fingerspelling is hard for adults to acquire. This has led some instructors to develop curricula specific to this aspect of the language in order to help students improve their production and comprehension of fingerspelling. Many ASL curricula are developed based on anecdotal evidence rather than on theory-driven, empirically-tested methods of foreign language instruction. As I will suggest in Chapter 2, one goal of this project is to begin pushing the field of L2 ASL instruction into empirically-tested waters, rather than relying solely on instructor intuition.

This dissertation reports the development of an explicit training program designed to help ASL students improve their ability to understand fingerspelling. Then the efficacy of that training program will be assessed. Given the differences between fingerspelling and the ASL lexicon, improved understanding of how fingerspelling is used and processed is needed to aid learners. The primary motivation for this project is the lack of empirical explanation for why students struggle with this aspect of language acquisition more than others. I seek to fill a pedagogical gap in how to ameliorate this issue. In addition, this dissertation offers several unique contributions to two important lines of research. First, it represents a first-step in assessing pedagogical tools used in ASL teaching by applying the results of empirical investigations to classroom teaching, then developing materials based off of these empirical investigations. Second, it extends work on uses of explicit versus implicit phonetic training in second-language teaching and is the first to do so with learners of a language which is also in a different modality than their first language.

The remainder of this thesis is organized as follows. In Chapter 2, I review previous work related to this project. Broadly, this chapter explores three categories of work: studies of fingerspelling production, including rate of production; studies of fingerspelling comprehension in deaf adults and hearing second-language learners; and studies of explicit phonetic training in second (spoken) language teaching. Chapter 3 describes how the explicit and implicit (control) trainings programs were developed. Experiments testing the efficacy of the explicit training program are detailed in Chapters 4 and 5. Chapter 6 provides concluding remarks, including a discussion of studies that logically follow from this one.

A note about this document

Readers viewing this document electronically should note that it is interactive. Click on chapter, appendix, figure and table numbers in the text to be taken to the page on which they appear. For full reference information in the bibliography, click on in-text citations Throughout this dissertation I also provide hyperlinks to sample videos. Click these to be taken to the website where you can view these videos; a password will be required. Readers who do not have the password should contact the author to request it. For readers using a hard copy of this document, a full list of URLs for video links is available in Appendix H.

Chapter 2

Literature Review

This chapter provides an overview and synthesis of previous work on fingerspelling production and comprehension. Production studies address examinations of fingerspelling rate as well as variation found therein. This topic necessitates a discussion of fingerspelling rate because much of the variation attested in fingerspelling production is a direct result of the speed with which it is produced and its frequency of occurrence in ASL texts. From there, I move into a review of work on fingerspelling comprehension, beginning with examinations of skilled signers – both deaf and hearing – followed by studies of ASL students. The literature demonstrates that fingerspelling comprehension is a difficult task generally, but there appear to be differences in how skilled and novice learners approach the task, leading to large performance discrepancies. It is conceivable that part of the difficulty ASL learners experience with fingerspelling comprehension is the result of the rate at which it is produced, but this does not appear to be the only factor impacting their very poor overall performance. I conclude this chapter with a discussion of literature on phonetic training in L2 teaching and how that literature might inform adoption and use of this type of instruction in ASL classrooms in the future.

2.1 Rate of fingerspelling production

Fingerspelling is a frequent occurrence in ASL texts; estimates range from 10-20% of the discourse depending on signer, topic, and audience, among other factors (Morford and MacFarlane, 2003; Padden and Gunsauls, 2003). Many researchers have noticed interesting phonological changes – like lexicalization of fingerspelling, which was discussed briefly in Chapter 1 – that are likely a result of the prevalence with which it occurs in this language. In this section I review several analyses of fingerspelling production, some of which were designed to examine rate of production as well.

To better understand the phonetic realization of fingerspelling, Thumann (2009) analyzed 23 instances of the word M-O-B-I-L-E as produced by two deaf women conversing with each other; both were from Mobile, Alabama. Thumann noted several general trends in her analysis. She found that the duration of tokens decreased as the conversation progressed, but when M-O-B-I-L-E had not been used for some time, it took longer to articulate when it was re-introduced into the conversation. This pattern may be likened to the hyper- and hypospeech model (Lindblom, 1990). According to this model, phonetic variation is related to the dynamic nature in which speakers can adapt their performance to certain situational demands while bearing in mind the needs of their listener(s). In Thumann's study, both signers were aware of their interlocutor's familiarity with the city of Mobile as they both resided there. Consequently, their productions of the fingerspelled M-O-B-I-L-E could get progressively faster and involve more coarticulation without compromising intelligibility. In addition to the temporal changes in production, and likely as a result of them, Thumann noted different phonetic realizations of each of the letters depending on the token in which they were produced. Notably, the letters -I- and -L- were frequently coarticulated resulting in what is often referred to as the ILY handshape, pictured in Figure 2.1.

Figure 2.1: Handshape referred to as ILY because it has features of the letters -I-, -L-, and -Y-. The extended pinky is involved in the letters -I- and -Y-, the abducted thumb is involved in production of -Y- and -L- and the extended index finger is involved in the production of -L-. Refer back to Figure 1.1 in Chapter 1 to see citation forms of each of these manual letters.

While it was not Thumann's specific aim to investigate rate of fingerspelling, the fact that the duration of fingerspelling decreased with successive mentions of the same word ended up being significant. This unanticipated finding also demonstrated the relationship between coarticulation and rate of production. This makes sense logically: Given its frequent rate of occurrence, fingerspelling has to be articulated quickly in order to convey propositions at a comfortable rate of around 2.3 signs per second (Klima and Bellugi, 1979; Hwang, 2011); therefore signers cannot produce canonical, citation forms of each of the letters. There simply isn't time, just as there is not sufficient time to carefully articulate spoken words as they might be produced in isolation in order to achieve typical (English) speaking rates of 150-215 words per minute (2.5-3.6 words per second), depending on topic and interlocutor (Yuan et al., 2006). Other studies of fingerspelling have specifically probed the data for rate of production information. Several are reviewed briefly below.

Studies of fingerspelling rate often feature rate calculations which involve taking the total duration of the utterance from the first to the last hold – portion in which the hand is held static – and dividing that by the number of letters in the target (English) word. The resulting figure, then, reveals an average value representing how many letters are articulated per second. Previous works which have used this approach are summarized in Table 2.1. This equation obscures the fact that not all letters have the same inherent durations (Keane, 2014). Additionally, it requires that the total duration of the fingerspelled utterance be divided by the total number of letters in the English word. This ignores the fact that words may be misspelled but more importantly, it assumes that the English character string length is equal to that of the ASL fingerspelled string length. Keane demonstrated that this is not the case. Consequently, the orthographic character may not be the right unit by which to segment fingerspelled utterances.

Author(s)	**Subject(s)**	**Rate**
Zakia and Haber (1971)	staff members at a university for the deaf and hard of hearing students	6.71 LPS
Wilcox (1992)	two signers fingerspelling B-U-T (extracted from larger segment of text)	4.69 LPS
Jerde et al. (2003)	ASL interpreters	3-4 LPS
Quinto-Pozos et al. (2010)	two native Deaf signers fingerspelling in different settings	8.41 LPS
Geer (2013)	native signers fingerspelling from a word list in different speed conditions	3-8.51 LPS
Keane (2014)	native signers fingerspelling from a word list	5.84 LPS

Table 2.1: Summary of previous work on fingerspelling rate; figures are reported in letters per second (LPS)

More recent work has attempted to refine calculations of fingerspelling rate to address some of the confounds mentioned above. Keane (2014) studied a corpus of fingerspelling productions by native and early signers, all of whom are deaf. Rather than using English orthographic characters as the unit of measurement, he examined the number of *apogees*, or periods during which the hand was stable or very near stable. This is relevant because in some cases, the canonical manual representation of orthographic characters is not realized but the hand is still stopped. Furthermore, sometimes the apogees that are achieved are combinations of two letters, usually those that co-occur with high frequency; recall the case of L-I co-occurring, pictured in Figure 2.1 (Thumann, 2009).[1] This is an important point which I will return to in Chapter 3 when I describe why the intervention training was designed as it was. Crucially, there is not always a one-to-one correspondence between orthographic characters and stable segments in fingerspelling.

Despite the problems with the commonly-used rate formula, Keane (2014) calculated the rate of production in his data set for the purposes of comparing his data with previous work. The average rate of production was 5.84 letters per second. Other relevant calculations were also conducted which previous works did not have the opportunity to examine. Specifically, he was able to examine how long each of the hold and transition segments lasted.

Keane's dissertation unveiled several important findings but two are the most relevant to the present chapter and to this dissertation project as a whole. First, with careful calculations of how long hold and transition segments are in fingerspelled words of varying lengths, he demonstrated that calculating rate by dividing utterance duration by the number of letters is but a first approximation because there are many factors which impact how long manual letters are realized. Some of these factors include the location of a letter in a word, the number of letters in the word,

[1] Keane (2014) noted six such co-occuring digraphs in his thesis.

and the signer who is producing the fingerspelling. Keane also demonstrated that the extent to which letters are coarticulated in fingerspelling makes the letter itself an inappropriate unit by which to calculate rate. Because some digraphs or even trigraphs co-occur so frequently, they are often realized as a single unit or *apogee*.

These discussions of fingerspelling rate and the variation resulting from coarticulation therein relate to the task of fingerspelling comprehension and the challenges it presents in language acquisition. Successful fingerspelling comprehension hinges on the ability of the visual system to quickly reconcile sometimes subtle and highly variable changes in handshape and/or orientation. Second-language learners seem ill-equipped to handle this task. In particular, they are taught to search for cues like canonical handshapes, which may not be there. It should be unsurprising, therefore, that they struggle so much with fingerspelling comprehension. If students can be taught about the type of variation within the fingerspelling signal they should expect, they should better be able to conquer the task of fingerspelling comprehension. The next section reviews studies of fingerspelling comprehension in both skilled deaf signers and hearing L2 adult learners.

2.2 Fingerspelling comprehension in deaf adults

This section summarizes work on fingerspelling comprehension in deaf native signers, highly proficient deaf and hearing L2 signers, and hearing adults acquiring ASL as their second language. It should be noted that not only is ASL a second language (L2) for these hearing individuals, but it is also a new language in a new modality. Because the extent to which differences in modality may impact second language acquisition are not fully understood at this time, several researchers have used "M2" to differentiate this group of learners from those who are acquiring a new language in the same modality as their first (Chen Pichler, 2009, 2011; Ortega-Delgado, 2013). For the purposes of this dissertation I use the term L2, but it should be noted that they are also M2 learners.

Hanson (1981) tested 17 deaf native and near-native signers in a fingerspelling comprehension task. Of these, 15 had acquired ASL from birth while two acquired it beginning at age five. Experienced ASL users indicated that these two near-native participants were indeed proficient users of the language. Two questions drove this experiment: *(1) How are fingerspelled words read?* and *(2) Is reading fingerspelled words a letter-by-letter process of recognition?* Participants were tasked with writing down the word they had seen fingerspelled and determining whether the item was a real word of English. There were 60 test items, 30 of which were real words, 20 were pseudo words (forms that are phonotactically licit in English but not real words), and 10 impossible words (completely illicit forms in English). Full results from the study are presented in Table 2.2. Here, "total correct responses" refers to items for which participants correctly wrote the word that had been fingerspelled regardless of whether they correctly identified the token as a word of English. "Correct word judgments" refers to items for which participants correctly identified real words of English as such. Finally, "correct spelling following correct word judgement" refers to only the subset of tokens for which participants correctly identified them as words or non-words *and* correctly spelled them back in written form. Results for real English words revealed that while participants often understood the fingerspelled word – the researcher noted that they would sometimes produce a signed translation equivalent for that word – they still could not spell it correctly in their written response. They responded with the correct spelling in only 62.9% of cases but correctly identified that an English word was indeed a real English word 92.9% of the time.

	Words	Pseudowords	Impossible words
Total correct responses	61.0%	25%	11.2%
Correct word judgments	92.9%	83.5%	82.9%
Correct spelling following correct word judgement	62.9%	28.1%	12.9%

Table 2.2: Mean percentage of items correct in the three conditions reported in Hanson (1981).

Hanson also examined potential sources of errors in fingerspelling comprehension. These were often related to English orthography, to phonetic misspellings, and also to deletions, transpositions, substitutions, and additions of letters. Relevant to the present discussion, Hanson found that words with certain letters proved more difficult than others. The letters -A-, -E-, and -O- were problematic, likely because they have similar visual forms, as do other compact letters including -M-, -N-, -S-, and -T-. Substitution errors often resulted when these letters were used. The pair -I- and -Y- proved difficult because the crucial difference between these handshapes is only the position of the thumb. Finally the pair -P- and -K- often led to comprehension errors.

Hanson (1981) demonstrated that fingerspelling is a challenging task even for skilled signers and that they are sensitive to visual similarity of the letters that comprise the word. What is not clear from this experiment is what cues within the fingerspelling stream signers are using to understand each token. Wilcox (1992) posited that successful comprehension rests on the transition segments in fingerspelling because they are the most information rich portion of the signal. Hanson's results revealed that her participants were able to assign meaning to fingerspelled utterances but not necessarily be able to spell them back again, so it is not exactly clear what cues they were using to arrive at that meaning. The next study I describe examines this issue by isolating certain sources of information within the fingerspelling stream to see how this impacts word comprehension.

Schwarz (2000) designed an experiment to isolate the information provided by transition segments to determine whether Wilcox's assertion about transition segments was correct. Using video data of a person fingerspelling, she masked one hold segment – a span in which the signer holds a letter posture – within each word. The mask was created by replacing hold video frames with a magnified image of the signer's palm, with the fingers edited out. The configuration of the hand was imperceptible; see Figure 2.2. Deaf signers were asked to write down the word they saw fingerspelled on screen. This study tested whether the transitions around a hold segment provide all of the information needed to identify the letter, and then subsequently the word. This design afforded Schwarz the ability to assess what Hanson's design could not, namely, how cues within the fingerspelling stream relate to or influence comprehension.

Schwarz calculated her findings in three ways, two of which are relevant for the present work. The first approach, known as the Strict Approach, counted responses as correct only if they were an exact match to whichever stimulus was produced. For example, if the word H-A-P-P-Y were fingerspelled, only a written response of *happy* would be accepted as correct. The second approach was based on Akamatsu's *movement envelope* (1985); see Figure 2.3. Crucially, the movement envelope is characterized by the transitional segments between the hold portions of the signal. The hand approaches some target but it is not necessary to know what exactly the target is. The transitions provide information about the height of the next hold and perhaps also the selected fingers[2] for that target. If the stimulus item were

[2]'Selected fingers' are those which can change from open to closed, or closed to open, during articulation of a sign while unselected fingers must remain in the same position throughout (Brentari,

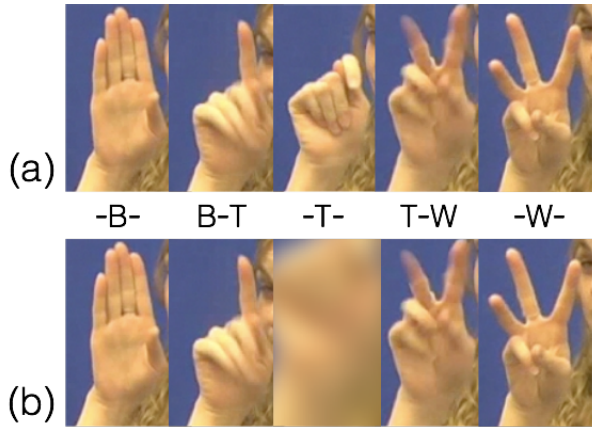


Figure 2.2: Recreation of stimuli according to description provided in Schwarz (2000). The (a) figure includes still images of the fingerspelled abbreviation B-T-W ("**b**y **t**he **w**ay"). The (b) figure includes a mask over the -T- hold created by zooming in on the signer's hand. The color clearly matches with the signer's hand, but the configuration of her hand is not distinguishable.

L-O-S-E-R, a written response of *loner* would be counted as correct because both -S- and -N- are short letters, which means the two forms have the same movement envelope or overall shape.[3] A response of *lower*, however, would be marked incorrect. Because -W- is a tall letter, its use would result in a different movement envelope

1990a, 1998). They can also be used in contact with the place of articulation. This distinction is sufficient for describing most types of handshape contrasts in the world's signed languages but the notion of 'secondary selected fingers' (Eccarius, 2002; Brentari, 2011) has also been proposed for situations in which the binary selected/unselected distinction is insufficient.

[3]Patrie and Johnson (2010) argue that the notion of "shape" in fingerspelling is a frequently perpetuated misconception because there can be no shape to something intangible. They claim that because perceivers are not able to "reinspect" the shape of fingerspelling after it has been uttered means the term does not apply. I argue this is an appropriate term because it is used more abstractly to refer to the visual "shape" created by the excursion of the hand through the signing space. So while it cannot be re-inspected after being uttered, the visual system can detect the shape the hand traces in the air.

than the original stimulus item. Each of these fingerspelled tokens is pictured in Figure 2.4. While actual hold segments are pictured in this figure, the same shape would be apparent if only abstractions were represented, like Akamatsu's S-A-F-E-W-A-Y graphic presented in Figure 2.3.

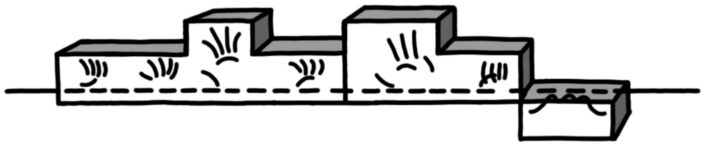
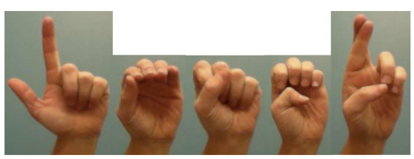
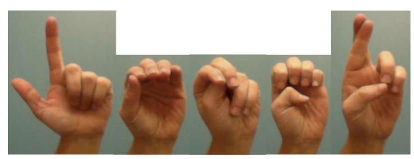


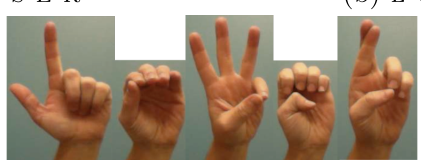
Figure 2.3: Re-creation of Akamatsu's visualization of the movement envelope for the fingerspelled word S-A-F-E-W-A-Y. The schematic depicts the perceived contour of the item rather than the specifics of each letter individually. This figure can be read as "two short letters followed by a tall letter, followed by short, tall, and short letters, and ending with an extra short letter." The fact that the -Y- is "extra short" is described in Chapter 3.



(a) L-O-S-E-R



(b) L-O-N-E-R



(c) L-O-W-E-R

Figure 2.4: Three fingerspelled items. Items (a) and (b) both count as correct according to the Envelope Approach in Schwarz (2000), however (c) is incorrect because, unlike -S- and -N-, the fingerspelled letter -W- is tall, thus creating a different movement envelope.

The results for both the Strict and Envelope Approaches are summarized in Table 2.3. Participants performed much better when their responses were evaluated with the envelope approach as compared to the strict approach. This suggests that, while transitions are sometimes insufficient for correctly identifying the fingerspelled word, they do give some clue as to the overall shape. Because the hold segment is masked, participants must have used transition information to identify at least the height of the obscured handshape in order to give a correct answer under the envelope approach. If this weren't the case, we would expect equal or worse accuracy when evaluated with the envelope approach, not better. Thus, use of the shape of fingerspelled words appears to help signers comprehend them. However, Schwarz (2000) states in her thesis that she "...is unclear as to the practical significance of the Envelope Approach finding" (p. 73). Results from a more recent study bear on the practical significance of these findings and are discussed subsequently.

Strict Approach			**Envelope Approach**		
Word length	*Unmasked*	*Masked*	*Word length*	*Unmasked*	*Masked*
Short	94.7%	60.4%	Short	96.0%	81.3%
Long	81.3%	58.8%	Long	86.7%	70.7%
Total	88.0%	57.1%	Total	91.3%	76.0%

Table 2.3: Average correct responses in masked and unmasked conditions and in Strict and Envelope analyses from Schwarz (2000).

Wilcox (1992) suggested that transitions should be more useful for successful word identification than Schwarz found to be the case. Transitions have been found to be important for word identification in spoken language. Transitions in spoken languages provide enough information for listeners to recover acoustic information that had been deleted or truncated from the signal. Holt et al. (2000) found that listeners were sensitive to the information provided by formant transitions to vowels from different consonants. Jusczyk et al. (1981) showed that participants were equally consistent in identifying the consonants /b/ or /d/ in CV stimuli whether they were provided with the full sound clip or only the first 30 milliseconds.

Considering the findings of Holt et al. (2000) and Jusczyk et al. (1981), among others of this type, one explanation for why fingerspelling transitions would be more information-rich as compared to holds is that they could be temporally longer, which is the case for speech. Wilcox (1992) assumed this to be the case for fingerspelling. Keane et al. (2013c), however, demonstrated that this is not necessarily so. In fact, native signers vary greatly with respect to how long they spend in hold or transition segments. Some signers have very long transitions comprising about 70% of the signal, while other signers have rather long holds, accounting for around 70% of the fingerspelled item.[4]

In closing her thesis, Schwarz (2000) suggests several logical ways to build from her work on fingerspelling comprehension. One of these suggestions is particularly relevant. She notes that "... fingerspelling is a linguistic system with built-in intrinsic redundancies that aid in ... perception" (p. 80). Transitions between letters – potentially containing information about the previous and or subsequent segments – the movement envelope, and canonical handshapes, when they occur all benefit listeners to varying degrees. Thus, a logical next step is to examine which of these built-in redundancies in the fingerspelling stream is the most useful cue for successful word comprehension. The pair of studies detailed next examine this question.

[4]The hold-to-transition ratio, in addition to varying signer to signer, also varied within signers depending on the length of the word (see Keane et al., 2013c, for details).

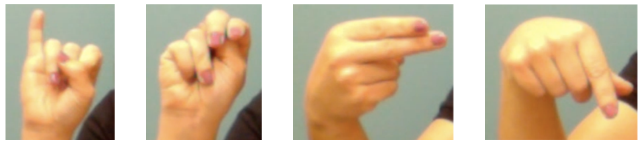
2.3 Fingerspelling comprehension in hearing L2 learners

Geer and Keane (2014) also used masking in an attempt to isolate cues viewers may attend to when they see fingerspelling. Instead of masking a single hold at the beginning, middle, or end of the word as Schwarz did, Geer and Keane masked each of the holds or transitions in a fingerspelled utterance to create two experimental conditions. In addition, and relevant to the point above about timing in fingerspelling, the signer who produced these stimuli had a relatively even ratio of hold to transition duration. This means that of the total time spent producing each fingerspelled token, roughly equal parts were spent articulating holds and transitioning from one hold posture to the next. Consequently, any differences in ability to successfully comprehend a word with either transitions or holds can only be attributable to the information in the portion of the signal that was available, and not related to the length of time to which the perceiver was exposed to that portion of the fingerspelling signal.

Unlike Schwarz (2000), who studied deaf signers, Geer and Keane (2014) examined fingerspelling comprehension among anglophone, second-language learners in their third-semester of ASL instruction. Participants watched video clips of fingerspelled items produced by a native signer. A black screen mask was inserted for the duration of each of the transitions for the *holds-only* condition and for the duration of each of the holds to create the *transitions-only* condition. This study demonstrated that student learners perform better when provided with only the hold portion of the fingerspelling signal. This is perhaps counterintuitive given Schwarz's findings from her study of skilled signers, who were able to use transitions to extract some information from the fingerspelling stream. Student learners seem unable to do this. Schwarz argued that the redundancies in the fingerspelling stream offer multiple cues for word identification. These include use of the movement envelope, canonical handshapes in certain positions, and information carried in the transition portions of the utterance. Her study demonstrates that skilled signers are able to appropriately weight the cues she mentioned to successfully comprehend fingerspelling, even though introduction of the mask made comprehension somewhat more challenging. Second-language learners seem to weight canonical handshapes most heavily while Schwarz's findings suggest that deaf signers focus more on the movement envelope/information in transition segments.

In a larger follow-up study to Geer and Keane (2014), Keane and Geer (2016) showed that, in addition to performing significantly better in the *holds-only* condition, errors are strongly predicted by the non-default palm orientation of certain manual letters. Most manual letters are produced with the wrist extended or slightly hyperextended, elbow flexed past 90 degrees and the forearm rotated such that the palm is facing outward; signers can see the backs of their own hands. Several letters are produced with a different orientation which does not conform to this default. The letters -G-, -H-, -P-, and -Q- face inward and -P- and -Q- also face downward. Figure 2.5 gives several examples of fingerspelled letters produced with default and non-default palm orientation. In Keane and Geer (2016), fourth-semester ASL students correctly identified fingerspelled words 56% of the time. Their performance on items with non-default orientation letters was worse; 32% were correctly identified. This difference is statistically significant.

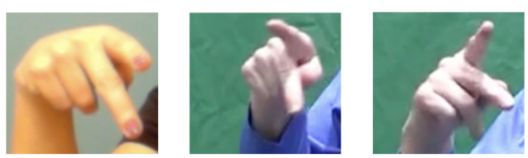
An additional complication with the fingerspelled letter -P- is that some native and near-native signers distinguish -K- and -P- not with wrist flexion as is the case in citation form, but rather with a (sometimes slight) orientation change, an inward rotation, or *supination* of the forearm; see Figure 2.6. This may lead to the



(a) (b) (c) (d)

Figure 2.5: Several citation forms of fingerspelled letters. Figures (a)-(b) show the default palm-out orientation; the signer can see the back of their own hand. Figures (c)-(d) show non-default orientations; (c) has the palm in and (d) has the palm facing inward and down.

specific error of misreading the letter -P- as -K-, just as Hanson (1981) found in her study. Errors involving confusion of -K- and -P- were particularly prevalent. One of the practice items in both Geer and Keane (2014) and Keane and Geer (2016) was P-L-A-C-E; the first hold of this token is pictured in Figure 2.6c. Despite being told that all words in the experiment were real words of English, the vast majority of participants (97%) still responded with *klace*. Similarly, in a recent fingerspelling activity with my own students, several (13%) responded with *Kortugal* when the category of fingerspelled words was "countries in Europe" and what had in fact been spelled was P-O-R-T-U-G-A-L.



(a) (b) (c)

Figure 2.6: Productions of -P- by two signers. Both (a) and (b) show a more canonical production of -P- with flexion at the wrist, while (c) features only very slight flexion at the wrist and inward rotation, or supination, of the forearm. Tokens (b) and (c) are produced by the same signer.

That non-default letter orientation, which has larger movements than words formed with all default orientations, so strongly predicts errors in student signers is surprising for two reasons: (1) Wilcox posits that transitions are more important than holds for word comprehension, and (2) other work suggests that transitions, or at least the overall shape of fingerspelled utterances formed by the transition movement, is significant.[5] If transitions really are as crucial for accurate word comprehension as others have noted, students should do better on this subset of items, rather than worse.

Akamatsu (1985) showed that children acquiring ASL fingerspelling first produce forms following the movement envelope; refer again to Figure 2.3. Children are unable to produce adult target forms in fine detail, but do accurately capture the overall movement contour of fingerspelled words. Padden (2006) built on this work by demonstrating that the process by which children acquire fingerspelling is different from that of L2 adults, as the former go through two distinct phases. Children first go through the process Akamatsu describes. Then, as they develop literacy, they go through a period in which their ability to produce fingerspelling declines as they become aware of the relationship between English letters and their manual representations in ASL. As their literacy improves, they are once again able to produce the adult(like) target, involving the overall shape of fingerspelled words. As their dexterity improves, so too does their ability to correctly form individual manual letters, all while retaining the movement envelope.

Those who acquire fingerspelling in adulthood, or even after acquiring some level of English literacy in childhood, do not follow this two-step process. From their first exposure to fingerspelling, they understand the mapping between orthographic characters and their manual representation. This seems to impact their ability to see

[5]There may be an extent to which holds also contribute to the movement envelope but it seems that transitions do so to a greater extent because they are more visually salient (Brentari, 1998; Stone et al., 2016).

the holistic shape that children are so attuned to at a young age and which adults remain sensitive to (Stone et al., 2016).

Additional evidence that transitions are important for fingerspelling comprehension and that skilled users are sensitive to these cues, while students are not, comes from a study of *local lexicalization*. Brentari (1998) details how longer fingerspelled items that are produced repeatedly in a discourse undergo local lexicalization.[6] In these locally lexicalized forms, the features of the full fingerspelled word that are retained are those that involve the biggest excursions through the signing space and are therefore likely to be more salient[7] to the perceptual system. Figure 2.7 provides an example of local lexicalization. This process retains the larger movements like those introduced by manual letters with non-default palm orientation. So, while the original fingerspelled word has 10 holds, one for each of the letters in English, the locally-lexicalized form retains at most four holds, one for the letters -M-, -P-, -H-, and -Y-. It could be, however, depending on the signer, that there are only two holds – -M- and -Y- – and the letters -P- and -H- are made in transition between them. Crucially though, transitions from each of these letters to the next requires a change in orientation, which is more visually salient than the transition from -M- to -O-.

[6]The term "local" refers to the context of utterance. Some lexicalizations are not widely accepted but rather are coined *locally* for a specific discourse, then perhaps not used subsequently, or must be re-coined in future discourse.

[7]There is often no empirical basis to the use of this term so future studies should establish an more objective definition. Here I use the term to refer to features of linguistic utterances which are judged to be more apparent to the perceptual system, perhaps because they are louder, longer, brighter, or more contrastive.

Figure 2.7: Local lexicalization of the word M-O-R-P-H-O-L-O-G-Y from Brentari (1998)

This set of letters, -G-, -H-, -P-, and -Q-,[8] are the same as those that strongly predicted comprehension errors in student learners in their second year of ASL acquisition. Testing the rules Brentari (1998) proposes to govern local lexicalization, Stone et al. (2016) asked whether signers are in fact sensitive to highly sonorous locally-lexicalized forms in much the same way hearing adults are sensitive to sonority constraints in spoken languages (e.g., Berent and Lennertz, 2010). While a discussion of whether *sonority* as applied to signed languages is the most appropriate term to use in this context is beyond the scope of this dissertation, it should suffice to clarify how it is being used here. Researchers (e.g., Brentari, 1998) have argued that as *sonority* in spoken languages refers to those parts in the speech stream that are most acoustically salient, sonorous segments in signed languages are those which are *visually* salient; primary movements are considered to be the most visually salent aspects of signs. Participants were presented with carefully fingerspelled low-frequency

[8]The manual letters -J- and -Z- are also in this set. However, none of the test items in either Geer and Keane (2014) nor Keane and Geer (2016) included words with these forms.

words of English and then with high- and low-sonority lexicalized forms and asked which they would prefer as a lexicalized variant of the carefully fingerspelled word. The 35 deaf adults tested preferred high sonority forms, those that retained large movements, 83% of the time, while 52 sign-naïve adults performed at chance, preferring highly sonorous forms only 52% of the time. This difference between groups was statistically significant. The Stone et al. (2016) study suggests the importance to skilled signers of the transition into, and out of, non-default orientations. Transitions to and from targets with non-default orientation are generally longer (Keane, 2014) and this movement is visually salient for skilled signers.

In light of these findings, it is curious that transition movements, while so important for skilled signers, are such an impediment for student learners attempting to correctly identify fingerspelled words. Perhaps then it is not the case that Wilcox was incorrect about the importance of transitions for fingerspelling comprehension but the extent to which they are helpful varies depending on one's language background/experience with the language. The purpose of this investigation is to determine whether student learners can be trained explicitly to make use of these various other cues in the way it seems skilled signers do. The next section summarizes research which has investigated studies of cue re-weighting and explicit phonetic instruction in second language learning.

2.4 Phonetic instruction and training in L2 learning

Explicit instruction is present in teaching if a "rule explanation forms part of the instruction (deduction) or if learners are asked to attend to particular forms and try to find the rules themselves (induction)" (Dekeyser, 2003, p. 321). A variety of work has examined the merits of explicit instruction in second-language learning, however much has focused on grammar-learning, rather than pronunciation. Instead, teachers, many of whom have no training in phonetics, are left to rely on their intuitions regarding how to teach students. Without empirically-tested pedagogical tools, teachers must train students to recognize and produce phonetic segments not used in their L1 (Derwing and Munro, 2007). This lack of empirically-grounded teaching materials is consistent with Thoryk's (2010) argument about a similar trend in ASL teaching which has persisted since the field's inception.

The comparatively few studies which have tested the use of explicit instruction for pronunciation have revealed positive results (e.g., Couper, 2003; Derwing et al., 1998; Macdonald et al., 1994). Here I summarize common methods used in explicit phonetic instruction in foreign-language teaching and discuss the ways in which findings from these studies may inform work on explicit instruction for learners of ASL as a second language.

Ylinen et al. (2010, among others) noted that one reason L2 learners struggle in phoneme and word identification tasks is because cues to phoneme recognition differ from their L1 to L2.[9] Crucially, native speakers know how to appropriately weight various cues such that they are highly successful in identifying different phonemes. This is not necessarily the case with L2 learners, especially when cue weights conflict between their L1 and L2. A good example of this is vowel identification in English speakers versus Finnish or Greek speakers (Ylinen et al., 2010; Giannakopoulou et al., 2013). In Finnish and Greek, vowel length is phonemically contrastive but this is not the case for English. However, this does not mean that all vowels have equal length

[9] It is not the case with ASL learners that they are experiencing interference from their L1 phonology, but they still have to learn how to appropriately weight cues in their L2, which also happens to be in a new modality.

in English, but it means that English speakers know (subconsciously) to ignore that cue, or at least to give it very little weight.

Ylinen et al. (2010) designed an experiment to compare L1 and L2 cue-weighting among native English and L2 Finnish speakers, and to assess whether that weighting system can be altered with training. They tested 12 native Finnish speakers with intermediate to advanced English skills, as well as 13 native English speakers from the US, Canada and the UK. Using 19 English minimal pairs distinguished by the vowels /i/ and /ɪ/, they tested how accurately participants identified the correct word. With natural stimuli, participants performed equally well, but when vowel length was made equal (/i/ is typically longer), Finnish participants scored poorly. Finnish speakers (incorrectly) heavily weighted the cue of vowel length, because it is contrastive in their L1, over the most relevant cue of tenseness.

Finnish speakers then completed a training program in which they listened to four speakers (two males and two females) producing the same 19 minimal pairs on which they had already been tested. The training, consisting of highly-varied stimuli produced by speakers of different backgrounds, proceeded as follows: with correct responses, participants received feedback and advanced to the next trial; with incorrect responses, they received feedback and were made to repeat that trial. Participants completed 10 training sessions over a three week period, each lasting 20-25 minutes. A post-test revealed significant learning by the Finns. There was no difference between English and Finnish speakers, regardless of whether stimuli were natural or synthesized, demonstrating that cue-weighting can be altered with training.

Giannakopoulou et al. (2013) performed a similar study also on vowel discrimination with Greek adults and children. Additionally, they evaluated the efficacy of two types of training: one which used only natural stimuli and one which used both modified and natural stimuli. Like Ylinen et al. (2010), Giannakopoulou et al. found that cue-weighting can be altered (and with greater success in children than adults), but they also found that the training that combined modified and natural stimuli was most effective in teaching participants to re-weight cues to English vowel identification than natural stimuli alone. This suggests that forcing participants to be attentive to cues they otherwise ignore will help them learn to attend to cues they should weight more heavily.

Dekeyser's definition, participants in these studies were made to *infer* a rule about cue-weighting for English vowels, but it was never explained to them. Other studies have examined the effects of verbally explaining how to identify and produce phonetic segments found only in students' L2. Researchers like Schmidt (2001) have argued that this type of conscious knowledge about features of the target language is necessary for interlanguage development. Saito (2007, 2011) assessed the efficacy of explicit instruction in Japanese students learning English. Ultimately the goal was to improve their English pronunciation, but the training also involved an identification task, as research shows that language perception often precedes production (Flege, 1995, 2003; Kuhl, 2000).

Saito (2011) divided participants into two groups, one of which received explicit instruction on English-specific segments, while the other did not. The assumption driving this examination was that if learners were made explicitly aware of the phonetic features which characterize these segments, they would in turn be able to establish a strong mental representation of these sounds, leading to more native-like pronunciation. The training consisted of both identification and discrimination portions. The identification portion taught participants about the formal properties of certain English-specific sounds by focusing on place and manner of articulation, as well as the organs involved in articulation of those sounds. Next, participants were asked to produce the sounds they were taught. The discrimination phase involved teaching students about what Japanese segments they might mistake for English-specific segments, namely /æ/ vs /a/, /f/ vs. /ɸ/, /v/ vs. /b/, /θ/ vs. /s/, /ð/ vs. /z/. Participants then practiced producing both the Japanese segments and English segments, noting the ways in which they differed based on the articulatory characteristics they had been taught.

Results revealed that learners who received the explicit training for perception, as well as that for production, performed significantly better on measures of comprehensibility compared to the control group. This demonstrates that teaching students to become consciously aware of segment-specific features in the target language helped their speech to become more comprehensible. We can infer then, under the "perception first" view (again, see Flege 1995, 2003; Kuhl 2000) that their perception would have improved as well.

The studies described above demonstrate that explicit instruction can have positive effects on L2 outcomes, and thus, would perhaps also be effective for ASL students. There are, however, a few important differences to note. Again, ASL learners are acquiring a second language also in a second modality, so there is no competition from their L1 phonetic cues. Given the lack of interference from their L1, ASL students could be in little or no need of explicit phonetic instruction. However, independent of L1 modality, phonemes in any L2 will likely involve recognition and integration of multiple cues. Schwarz (2000) notes this is the case specifically with respect to fingerspelling. The cues in question include canonical handshape, transitions, the movement envelope, etc. Thus the practical significance of her movement envelope finding seems to be related to cue-weighting; skilled signers place a heavy weight on the shape of an utterance, even when they cannot make out all of the letters. It is quite possible then, that the reason students struggle with fingerspelling comprehension is simply because they are erroneously giving too strong a weight to the wrong cues. For example, Geer and Keane (2014) show that students are relying very heavily on the hold segments of fingerspelling while informal testing with skilled signers and extrapolated results from other studies (Hanson, 1981; Schwarz, 2000; Stone et al., 2016) suggest proficient signers weight this cue less heavily.[10] What I suggest and test in this dissertation is that, as in Ylinen et al. (2010) and Giannakopoulou et al. (2013), students can be taught to adjust the weights they have assigned to various cues in fingerspelling to improve their comprehension abilities.

An additional consideration to bear in mind is the method by which ASL learners are taught fingerspelling, as this could impact how they learn to comprehend fingerspelling. Li and Juffs (2015) noted that one factor affecting Japanese-accented English is the manner in which students are taught to read English characters. Instead of learning what sounds a particular letter can make individually, consonants are always paired with vowels as they are in the Japanese syllabary. Instead of learning something like "the letter 'r' says /ɹ/", students learn something like "the letter 'r' says /ɹa/". This, Li and Juffs argue, trains English learners to *always* produce vowels after consonants, whether the native English pronunciation calls for this or not. The case of fingerspelling may be similar. Because students learn manual representations of letters in isolation, they become too focused on seeing those specific forms without regard for how they can be influenced by the context in which they appear, namely, the letters which precede or follow them. Just as

[10]Formal testing is in preparation.

Japanese English students have to un-learn this CV pattern for correct English pronunciation, ASL students have to learn to focus on aspects of fingerspelling other than *just* the static portions of the signal. That is what this training program aims to remedy. In the next chapter I describe how I designed the explicit training program assessed in this dissertation and what motivated its development.

Chapter 3

Explicit & Implicit Training Programs

This chapter provides a detailed description of how the explicit training program assessed in Chapters 4 and 5 was developed. I also discuss the implicit fingerspelling training which was developed to serve as a control. The method of delivery for these training programs differed from the first to the second studies (Chapters 4 and 5, respectively), though the content remained the same. In Chapters 4 and 5, I describe the way in which the content of the explicit and implicit training programs was delivered to participants. Before I delve into these topics, I begin with a point of departure: a study which assessed the efficacy of a curriculum meant to improve ASL students' fingerspelling comprehension skills.

3.1 Assessing the efficacy of a fingerspelling curriculum

Thoryk (2010) tested the efficacy of a program designed specifically to improve fingerspelling comprehension. This program was developed by several individuals who based their curriculum on experience teaching in a community college. The program consisted of 16 lessons designed around several topics. Some lessons focused on comprehension of words and common abbreviations, while others dealt with specific skills related to the production of fingerspelling including location of production, rhythm, and how to produce double letters. Some lessons were not related to fingerspelling, but instead to numbers, and a final set of lessons were designed specifically to prepare students for the pre- and post-tests included in the curriculum.

Students from a large university with a main campus and several smaller regional campuses participated in this study. Teachers were mostly deaf, but not all, and most held at least bachelor's level degrees. Students were divided into classes that received the supplementary fingerspelling curriculum or classes that did not. Classes were balanced for the treatment and control groups on the following criteria: level of ASL (I-VI), teacher's hearing status (deaf or hearing), campus type (main or regional).

Results revealed that the supplementary curriculum was not effective in improving fingerspelling comprehension. In fact, students in the control group actually improved, on average, more than students in the treatment group, though this between-group difference does not appear to be statistically significant (Thoryk did not report any statistical measures). Furthermore, some students in the treatment group performed worse on the post-test than they had done on the pre-test.

There are two particularly relevant points from this experiment. First, there are very few studies which examine the pedagogical effectiveness of various teaching tools and styles, which is something that is desperately needed in the field of ASL teaching. This article demonstrates this point very clearly and encourages future work which would address this gap in the literature. Second, this article provides one very clear example of why scholars and teacher-scholars need empirically-based and theory-driven pedagogical tools. ASL curricula can benefit from research on second language learning and teaching and new work on ASL learning and teaching can inform this and other specialized curricula. Historically, the literatures on ASL pedagogy and second-language learning generally have not informed one another, yet there is much which can be gained on both sides. This dissertation may also serve as one way to introduce literatures on fingerspelling production and perception such that researchers in ASL pedagogy and second-language learning might work together in the future.

The fingerspelling program Thoryk assessed is based on impressionistic intuitions about how to teach ASL and not on theories of second language acquisition. As an example, training programs in which participants learned on stimuli from a variety of talkers, from multiple dialects, with target sounds in different acoustic contexts, have been used very successfully in spoken language L2 teaching (Jamieson and Morosan, 1986; Holt and Lotto, 2006; Lively et al., 1993; Saito, 2007; Ylinen et al., 2010; Giannakopoulou et al., 2013, just to name a few). The curriculum Thoryk assessed included only one model signer. Even students who participated in this study noted that they would have preferred exposure to more variation in fingerspelling. In this chapter, I demonstrate the ways in which empirically tested questions and application of research findings to classroom teaching have led to the program detailed here.

The remainder of this chapter is organized into two main sections. The first provides a description of the explicit training. I detail the ways in which its design is compatible with previous studies of successful explicit instruction approaches, many of which were discussed in Chapter 2 as well. I provide examples of production data from various sources to demonstrate the types of phenomena the training focuses on teaching. To do this, I refer primarily to data from three sources described below, though additional information is used as relevant. There are several advantages to considering fingerspelled data from a variety of sources. First, these studies were designed with very different research goals in mind. This means that similarities in productions that are identified cannot be the result of some idiosyncratic methodological choice in any one of the studies. It must be a trend in fingerspelling more generally. Second, each of these data sets was collected in a different area of the country. This means that similarities across data sets cannot be the result of some region-specific phenomenon. Finally, signers in each project represent different demographics so results across data sets cannot be the vestiges of some characteristic unique to a particular age group, for example.

- *Gallaudet production study (Washington, DC):* The purpose of this study (Geer, 2010) was to examine fingerspelling productions in two groups of deaf signers. The first group were native users of ASL and the second group had acquired ASL in adulthood. Only the productions of seven native signers will be considered for here. Data include productions of each letter produced in isolation, fingerspelled abbreviations produced in isolation, and finally, fingerspelled abbreviations produced in sentences created by participants. The advantage to this data set is that, in addition to fingerspelling in context, fingerspelled letters can be compared to each individuals' own citation form. A disadvantage to these data is that the context of fingerspelling production is not controlled. The signs before and after the target fingerspelled utterance vary from signer to signer, as does the position of the fingerspelled word within the sentence. Also, the fingerspelled items are not real words of English, but rather abbreviations commonly used in text messages at the time of data collection (2009-2010). Participants in this study were all undergraduate students at Gallaudet University.

- *UT Qualifying Paper study (Austin, TX):* This study (Geer, 2013) examined how age of acquisition may impact rate of fingerspelling production. Participants' age of acquisition ranged from zero to 19. Only the productions of native signers are included in this chapter. Data include fingerspelled words produced within the carrier phrase SPELL ... FINISH. Participants produced each test item at three different rates: normal, slow, and fast. The advantage to this data set is that the context in which fingerspelling is produced is carefully controlled. One disadvantage is that citation forms of each of the manual letters were not collected. However, Keane (2010) showed that there is less coarticulation in fingerspelling when it is produced slowly and thus productions at this rate are closer if not identical to citation forms. Still, it would have been ideal to have collected individual letter citation forms for each participant, but the tokens produced in the slow round can be used as a basis for comparison. Four native signers in the Austin area participated in this study. Some are adult professionals and some were UT undergraduate students at the time. As a supplement to this data set, where relevant, I mention data from a study which led to this QP project involving a single native signing participant (Geer, 2012).

- *Keane dissertation project (Chicago, IL):* This dissertation (Keane, 2014) provides a detailed analysis of fingerspelling productions from four native signers. Participants fingerspelled words from a screen, pressing a green button to advance to the next trial, or a red button to indicate they felt they'd made a mistake and wished to repeat that trial. There were no interlocutors but participants were told to imagine they were fingerspelling to another deaf native signer. In addition to hand-coded data, some data were collected and analyzed with motion capture technology. The biggest advantage to this data set is its volume. A disadvantage to this data set is that it is the least natural of the three sets discussed here. In order to collect a corpus of this size – 2,918 fingerspelled words – it would be impractical to have fingerspelling produced in context. Consequently, the corpus consists only of items produced in isolation. Only a subset of the tokens in this database are considered here. Participants in this study were deaf adults residing in the Chicago area. Three were women in their 50s and 60s, while one was a younger male in his early 30s.

The second major section of this chapter details the implicit training I developed as a control. Thoryk's study had no control curriculum. Had she uncovered a positive result, this might have been misleading. Specifically, it would be impossible to know whether that result was truly a consequence of exposure to the training or if it was simply the result of students in those classes having more dedicated time to work on fingerspelling. In the present intervention trainings, reported in Chapters 4 and 5, use of an implicit or control training allows us to discern with more certainty that differences in post-test performance are the result of the the type of intervention training and not just the result of more time interacting with a fingerspelling task. The content of the implicit training is guided by how fingerspelling is taught in the Smith et al. (2008) *Signing Naturally* text, which is the curriculum used at The University of Texas and in language programs throughout the US and English-speaking Canada.

Recall that Dekeyser (2003) stipulates that training is explicit when students are made aware of a rule for some aspect of their L2. In the program described here, the explicit training is one in which rules and generalizations are stated for students, who can then consider them consciously. The implicit training, while still focused on fingerspelling, does not provide students with rules about the structure of fingerspelling or the environments which condition certain types of phonetic variation. Examples of each of the trainings are given in subsequent sections and full versions of both programs can be found in Appendices A and B.

To complement the discussion of production data that follows, I sometimes offer a phonetic description of various aspects of fingerspelled letters. However, it is important to understand that there is no standardized tool for transcription like the International Phonetic Alphabet for spoken languages. Different transcription systems have been proposed and I briefly describe two below. In this chapter, when I describe the phonetic realization of signs, I use the second system.

The *Dictionary of American Sign Language* (DASL) provided the first systematic way to document the sublexical structure of signs (Stokoe et al., 1965). Stokoe et al. identified three aspects of signs that need to be captured in order to describe sign production; these are handshape, place of articulation, and movement. Stokoe et al.'s system includes 19 basic handshape symbols, 12 locations, and 24 movements. Orientation, now recognized as another formational parameter in signed languages (Battison, 1978), is indicated as part of the handshape notation in Stokoe's system, but refers only to the behavior of the forearm and elbow, but crucially, not the behavior of the wrist.

Stokoe Notation is fairly easy to learn and use; however, much information about sign formation cannot be unambiguously captured with this system. For example the symbol -G- is used to describe any handshape in which the index finger is extended, including the manual letters -D- and -G- and the number -1-, yet each of these is a distinct handshape; see Figure 3.1. Because the focus here is on phonetic rather than categorical distinctions in fingerspelling, a system which can capture more minute differences is required.

Figure 3.1: Example of three handshapes, each of which would receive the same designation using Stokoe et al.'s notation system, but which are minimally contrastive in fingerspelling and in the core lexicon. Other notation systems provide a means by which to distinguish these forms.

The phonetic notation system suggested by Johnson and Liddell (2011, 2012) (henceforth *J&L*) is designed to represent minor variations in hand configurations.[1] The system accounts for the behavior of each of the joints in the fingers and thumb, indicated in Figure 3.2. It also provides a means by which to characterize the relationship of the fingers to one another (i.e., spread/not spread apart, crossed) and the relationship of the fingers to the thumb (i.e., opposition of the latter). Orientation of the palm is annotated independently of hand configuration, which is relevant here for two reasons. (1) Sometimes the phonetic variation under discussion is not related to phonetic realization of a particular hand configuration, but rather to some be-

[1] A clarification of terminology: *Handshape* refers to the phonological form of the hand when producing signs and fingerspelling, and *hand configuration*, following Johnson and Liddell (2011); Whitworth (2011); Keane (2014), refers to the phonetic realization of a handshape.

havior of the wrist and/or forearm. (2) Letters that frequently co-occur may involve changes in palm orientation specifically in the wrist and/or forearm as well as changes in hand configuration. A full description of how to use the *J&L* system is beyond the scope of this dissertation but I provide a schematic of how hand configuration and orientation are transcribed to make later phonetic descriptions of fingerspelling more clear. This is available in Table 3.1. A more detailed explication of the system is provided in Appendix C. A complete description of configuration of the hand is available in Johnson and Liddell (2011, 2012). A description of orientation can be found in their forthcoming book which details the entire system; information used here comes from Johnson (2008).

Figure 3.2: Joints of the hand that require notation in the *J&L* system. The joints which contact the palm are known as the metacarpal phalangeal joints (MCP). For the four digits, the middle joint is known as the proximal interphalangeal joint (PIP), and the most distal joint is the distal interphalangeal joint (DIP). The thumb has no PIP, only an MCP and a DIP.

Hand Configuration

What to annotate	-L-	"double-z"
		
1. opposition of the thumb	no	yes
2. flexion/extension of the digits & thumb	thumb & index fully extended, digits 2-4 fully flexed	the thumb is partially flexed at one joint and fully so at the other, the index and middle finger are extended at the base joint, but flexed at the other two, digits 3-4 are fully flexed
3. amount of spread between digits & thumb	there is no spread between digits 1-4, but full spread between the thumb & index finger	full spread between the thumb & index finger, partial spread between digits 1-3, no spread between 3-4
4. thumb contact with other digit(s)	NA	tip of thumb contacts back of the second bone of the 3^{rd} digit

Palm orientation

1. wrist extension value	slightly extended	extended
2. wrist ab/adduction value	neutral	neutral
3. forearm rotation value	pronated	pronated

Table 3.1: Description of *J&L* notation for the handshape examples "-L-" and "double-z".

3.2 The explicit training program: Experimental group

The purpose of this training is to teach ASL students to make use of information in the fingerspelling stream that currently seems to inhibit successful performance (Geer and Keane, 2014; Keane and Geer, 2016). This includes information about the internal structure of fingerspelling as well as predictable types of phonetic variation present in naturally produced fingerspelled utterances. There are two main portions of the training: (1) understanding fingerspelling structure and properties of segments and (2) understanding variation in fingerspelling. Throughout this section, I discuss and provide examples of production data from several sources described above.

3.2.1 Fingerspelling structure and segments

The goal of this portion of the training is to draw participants' attention to the the differences between hold and transition segments. This is important for two main reasons. First, we know that students perform best when provided only with hold segments and poorly in transitions-only conditions (Geer and Keane, 2014; Keane and Geer, 2016). This suggests they are relying too heavily on the cues available in the holds segments, like static postures which may more closely resemble the citation forms they learned early in their first ASL course. Second, Li and Juffs (2015) show that there is an extent to which certain methods of language teaching can cause problems for learners. Their work shows that Japanese speakers learning English were unable to form a phonological representation of English consonants because they were always paired with a vowel. With respect to fingerspelling, we teach letters in isolation and students practice fingerspelling by looking at still images in a text book. This prevents them from appreciating the fact that fingerspelling is not only comprised of hold segments but also that which connects them to one another.

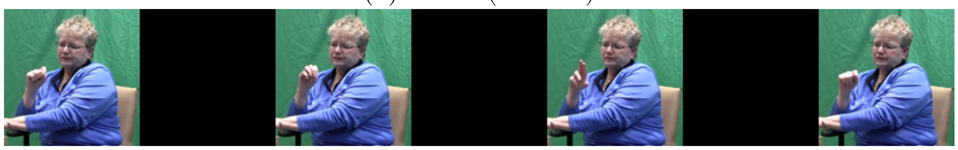
The purpose of this aspect of the training is to help students learn to identify and appreciate the different types of segments in the fingerspelling stream.

Consider the images in Figure 3.3. In hold portions of the signal, the video is clear and little-to-no movement, identified by blurring, is visible. Transition segments do exhibit blurring and the configuration of the hand shows features of the previous and/or subsequent letters. This means one could potentially use transition information to predict subsequent letters, leading perhaps to faster, or at least more accurate, lexical recognition. Recall from Chapter 2 that skilled signers seem to use transition information (Hanson, 1981; Schwarz, 2000; Stone et al., 2016), yet students perform worse in comprehension tasks when provided only with transition segments (Geer and Keane, 2014; Keane and Geer, 2016). In Figure 3.3b the letters -S-, -O-, -R-, and -T- can be clearly identified, while in Figure 3.3c the first image is slightly blurry and appears to have features of both -S- and -O-, the second with features of -O- and -R-, and the final one with -R- and -T-. One reason to teach students about the structure of fingerspelling and the different types of segments within fingerspelling, is related to the problem Li and Juffs (2015) noted about how foreign language phonology is sometimes taught. Because students are only ever taught about hold segments, many never consider what happens as the hand transitions from one hold segment to the next. They are not aware that this information can be useful and that it is something to which they should learn to attend.

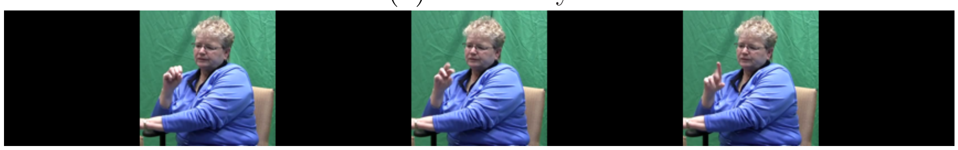
3.2.2 Phonetic variation in fingerspelling

The second, and longer portion of the training focused on teaching students about phonetic variation in fingerspelling as well as techniques some signers use to make fingerspelling appear more sign-like. The minimal word in ASL must have movement

(a) Clear (control)



(b) Holds only



(c) Transitions only

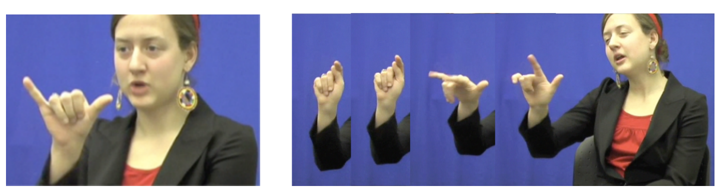
Figure 3.3: Example token in still images extracted from videos of the word S-O-R-T. The clear video (a) presents participants with unmodified stimuli – all portions of the signal are present. The holds only condition (b) presents stimuli in which the frames of transition are masked and the transitions only condition (c) provides the opposite; the frames in which a posture is held are masked. To view the videos from which these stills were extracted, click on the condition labels above.

(Brentari, 1998; Perlmutter, 1992; Brentari, 1990b,a; Sandler, 1993; Stack, 1988). As I describe below, epenthetic movements may allow fingerspelled forms to satisfy minimal word constraints. In Chapter 2 I noted that two reasons for the amount of variation attested in fingerspelling are its frequency of occurrence and the speed with which it is produced. This section presents information about the different types of phonetic variation given in the training including the manual letters -Y- and -E- and the combinations U-R and G-H-T.[2]

[2]Other types of variation and coarticulation could have been included however my goal was to keep the trainings as similar in length as possible. Topics for future trainings as an extension of the training described here are included at the end of the chapter.

3.2.2.1 -Y-

Geer (2010) found that native signers often add wrist flexion in the production of the letter -Y- in word-medial and word-final positions. This helps distinguish -Y- and -I-, which, in citation form, differ only by the position of the thumb. Hanson (1981), discussed in Chapter 2, found that these letters are sometimes easily confused. The epenthetic wrist flexion cues the presence of the letter -Y- even if the thumb undershoots its canonical abducted position. Consider the production of the abbreviation T-T-Y-L ("**t**alk **t**o **y**ou **l**ater") from the Gallaudet study in Figure 3.4; a schematic of the phonetic notation for hand configuration and orientation is given in Table 3.2. This wrist flexion also gives -Y- the appearance of an extra short letter as we saw in the Akamatsu (1985) example of the movement envelope with the word S-A-F-E-W-A-Y (refer back to Figure 2.3 in Chapter 2). The schematic phonetic notation in Table 3.2 illustrates the change in orientation of the palm in production of -Y- in isolation (citation form) and in context. In citation form, the signer's wrist is slightly extended (Figure 3.4a). In Figure 3.4b, the wrist if flexed slightly and the -Y- hand configuration exhibits perseveratory coarticulation from the previous letter -L-.



(a) (b)

Figure 3.4: Citation form production of -Y- by a native signer (a), followed by use of this letter in context in the abbreviation T-T-Y-L meaning "**t**alk **t**o **y**ou **l**ater" (b).

All production data sets considered here include tokens with the letter -Y- and all include instances in which the signer exhibits this characteristic wrist flexion.

Citation Form

Letter	HC	PalmOr
-Y-	-Y-	slight wrist extension

Context

Letter	HC	PalmOr
-T-	-T-	wrist extension
-T-	-T-	wrist extension
-Y-	-Y-	wrist flexed
-L-	ILY (w/ flexed pinky)	slight wrist extension

Table 3.2: *J&L* schematic notation for Figure 3.4

In the QP study, only one of four native signers used this technique some of the time, though the same signer used it consistently in the pre-QP study. Specifically, in the pre-QP study, this signer used wrist flexion for the letter -Y- in five of six tokens; in the QP study it appears in three out of three tokens in the slow and normal conditions, but in none of the three tokens in the fast condition. In the Chicago corpus, signers varied with respect to their use of this cue. One generalization based on the tokens considered here is that these four signers prefer this technique word-medially, more than word-finally. Specifically, two of the four signers produced -Y- with wrist flexion in the tokens H-I-M-A-L-A-Y-A and L-I-B-Y-A but one of the signers who did use wrist flexion in medial position, did not do so on the name K-E-L-L-Y. All seven native signers in the Gallaudet project used this technique for the abbreviation T-T-Y-L ("**t**alk **t**o **y**ou **l**ater"). Given this, there are three conclusions that can be made about production of the letter -Y-. First, it shows considerable individual variation. Some signers appear to use this technique most of the time, some use it some of the time, and some use it only rarely, if at all. Rate of production may influence this variation. Second, wrist flexion with -Y- is restricted to medial and final position; wrist flexion is never present word-initially in these data sets. Third and finally, this technique is specific to the letter -Y- and may be conventionalized to some extent; some text books, including *Signing Naturally* (Smith et al., 2008) have begun to specify that -Y- should be produced with downward orientation, though they have not identified the restricted distribution of this orientation in their text.

The explicit training program explains the distribution of the more canonical -Y- with a neutral or slightly extended wrist and the variant in which the wrist is flexed to some degree. This is done through explication of still photographs of these two fingerspelled letter variants – the wrist-extended variant appears word-initially and the wrist-flexed variant appears word-medially and word-finally. The training then presents a video, shown at half-speed, with several words containing the letter -Y- in various positions.

3.2.2.2 -E-

In a study of -E-, Keane et al. (2013b) found that its production varies greatly even among native signers. Several examples are provided in Figure 3.5 with schematic *J&L* notation in Table 3.3. The various ways in which this letter can be realized are conditioned by its phonetic environment. Keane et al. (2013b) noted several trends. For example, -E- is more likely to be open when it is immediately preceded by closed handshapes including -A-, -O-, -N-, -M-, -T-, -S-, and -X-. This maximizes the contrast between letters, presumably making their identification easier through dissimilation. Finally, open -E- variants are more likely word finally when the preceding handshape is closed.

It is interesting to note that this letter in particular has been shrouded in controversy in ASL teaching. It has been considered taboo to produce it any way other than canonically for ideological reasons – a false dichotomy of tendencies of hearing versus deaf signers – not supported by data. The text book indicates, despite offering variants for other letters, -E- must have "at least two fingers ... sit on the thumb" (Smith et al., 2008, p. 11). Productions that do not follow this requirement have been called a 'hearing person's -E-' or 'screaming -E-' (Vicars, 2015). Yet Keane et al. (2013b) show that, even among native (deaf) users of ASL, production of -E- varies greatly and includes the so-called 'hearing' or 'screaming' -E-. The training provided students with information about some of the different types of -E- they should expect to see in fingerspelling and the environments in which they can expect one variant or another. As data presented in Figure 3.5 demonstrate, even signers who hold very rigid beliefs about how -E- *should* be produced, produce it non-canonically in various contexts.

(a) (b) (c) (d)

Figure 3.5: Various productions of -E- by native signers. Examples (a)-(c) are produced by a signer form the Chicago corpus and the (d) example was excerpted from a video on YouTube. A clip of this token is available here. The (a) variant is known as the canonical form. It is called 'closed' because the index, middle, and (perhaps) ring fingers make contact with the thumb. The (b) form is known as 'open' because none of the fingers make contact with the thumb. The (c) variant is a type of open -E- which appears in the context of letters with selected index and middle fingers. In the case of this particular token, it is preceded by the letter -H- and followed by the letter -R-. The final variant, (d) is a word-final open -E- which was preceded by the letter -L- in the surname 'Poole'.

As Keane et al. (2013b) found, there is great variation in -E- production across data sets, although individual signers may prefer a particular form. For example, in the QP study, one signer never produced a closed (canonical) -E-, not even at slow

-E- Variant	Open/Closed	Fingers
(a)	closed	index and middle contact thumb
(b)	open	fingers equally flexed but non make contact
(c)	open	index and middle finger less flexed than ring and pinky
(d)	open	only index finger is involved in "-E-" production

Table 3.3: *J&L* schematic notation for Figure 3.5

speeds, suggesting her citation form is in fact an open -E-.[3] At the other extreme, another signer only produced two open -E- variants and they were always word-internally where a hold posture for that letter may not have been achieved; it was only made in transition. The other signers in the QP project were fairly balanced with respect to variation in -E- production, but they always had more open varieties in the fast rate condition than in the slow.

The explicit training addresses the variation in the fingerspelled letter -E- by presenting still photographs extracted from utterances with this letter. Participants first learn -E- variants which are considered *open* or *closed*. Students were presented with a list of the distribution of these forms based on Keane et al. (2013b). Next, the training provides an additional example of a way in which -E- can vary. Specifically, students saw a clip of the word T-E-A-C-H-E-R and then learned how and why each of the -E-s in that production are different. These differences are pictured in Figure 3.12 in an upcoming section of this chapter.

The cases of -Y- and -E- show how a single letter can be realized differently, but in predictable ways, as a result of phonetic context. These variants are used widely among native signers from various regions of the US and representing different

[3]Recall that a hold in fingerspelling produced at a slow speed often represent the signer's citation form for that manual letter (Keane, 2014).

age and gender demographics. The case of -Y- also demonstrates one way in which fingerspelling can become more sign-like, by epenthesizing movement which makes the form more visually salient. Helping students to develop conscious understanding of this variation and why it occurs should help to improve their understanding of fingerspelling (Schmidt, 2001).

3.2.2.3 U-R

This part of the training on phonetic variation in fingerspelling focuses on the bigram U-R. In citation form, the letters -U- and -R- are distinguished only by the relationship of the index and middle fingers. In -U- the fingers are fully adducted (touching each other) but in -R- they are crossing (middle over index). In U-R combinations, signers sometimes add ulnar deviation (bending of the wrist on the pinky side) and supination of the forearm (rotation so that the palm is facing upward) to mark this bigram, even if only one hand configuration is realized.

Consider the two words in Figure 3.6. Brentari (1998) suggests that in local lexicalization, it is the most visually salient features of a fingerspelled word which are retained. None of the letters in either of these words involves an orientation change, yet as can be seen in Figure 3.6, a movement is epenthesized in these and other tokens containing this bigram. This movement epenthesis is consistent with Brentari's proposed phonological rules governing local lexicalization but, instead of retaining a particularly salient aspect of a fingerspelled word, a visually salient feature is added, presumably to make an otherwise hard-to-differentiate letter combination more distinguishable. In this case, the epenthesized movement involves the addition of ulnar deviation (sideways flexing of the wrist toward the pinky) and supination (upward rotation) of the forearm, which taken together indicate the appearance of U-

R. In the examples in Figures 3.6a and 3.6b, neither letter is realized in its canonical form, but this extra movement indicates these letters as a unit. This movement does not occur in either letter individually, nor with the combination R-U. One likely explanation for the development of epenthetic movement with -U- and -R- but not the reverse is based on bigram frequency. Computer scientist Peter Norvig, building on the seminal work of Mark Mayzner (Mayzner and Tresselt, 1965), found that *ur* is the 50^{th} most frequent English bigram, occurring in 0.54% of words, while *ru* is far less common, occurring in only 0.128% of English words (Norvig, 2015). There are two tokens of fingerspelled words with R-U combinations in the Chicago corpus but neither of them exhibit this or any other sort of epenthetic movement.

(a)

(b)

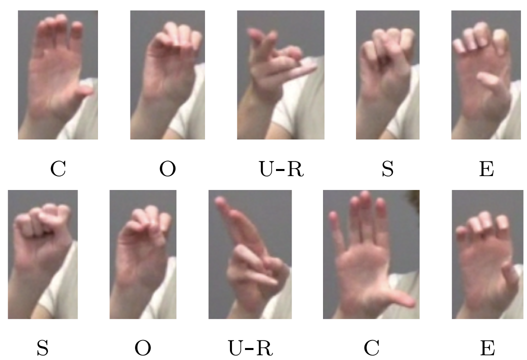


Figure 3.6: (a) C-O-U-R-S-E and (b) S-O-U-R-C-E naturally fingerspelled. (a) exhibits both ulnar deviation and supination of the forearm, while (b) exhibits the former only.

Tokens with U-R combinations are not available in the Gallaudet study but there are examples in both the QP and Chicago corpus projects. In the former, there are two tokens with this letter bigram and two of four signers produce the bigram with rotation of the forearm and ulnar deviation at the wrist. Upon consideration of the Chicago data, it appears that there are two variants for this bigram's co-production. One production involves a backwards crossing of the digits without forearm rotation and/or ulnar deviation, while the other involves at least the larger rotation/deviation movements. In the letter -R-, the (longer) middle finger crosses over the back of the index finger. In U-R combinations, sometimes rather than producing a canonical -U-, signers instead cross the index finger over the back of the middle finger. It also appears that there is some inter-signer variability. For example, one signer from Chicago always produced U-R combinations with forearm supination and ulnar deviation, while others may have produced them canonically, or with the backward finger-crossing.

Word frequency may predict when non-canonical forms are produced. For example, a signer who generally produced these letters as a unit in higher frequency words like S-O-U-R-C-E, C-O-U-R-S-E, and N-A-T-U-R-E, did not do so on the name M-A-U-R-I-T-A-N-I-A or the word T-U-R-Q-U-O-I-S-E. To explore this hypothesis, I used the Google Books Ngram viewer (Google, 2016). To use this tool, one types in various words or phrases, then sets the years of published texts Google should consider. Figure 3.7 presents a comparison of the frequency of several words with *ur* discussed here.

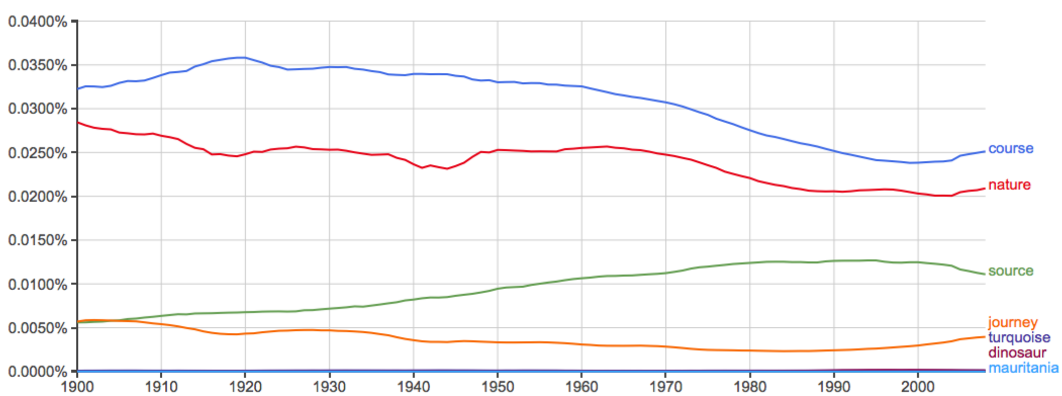
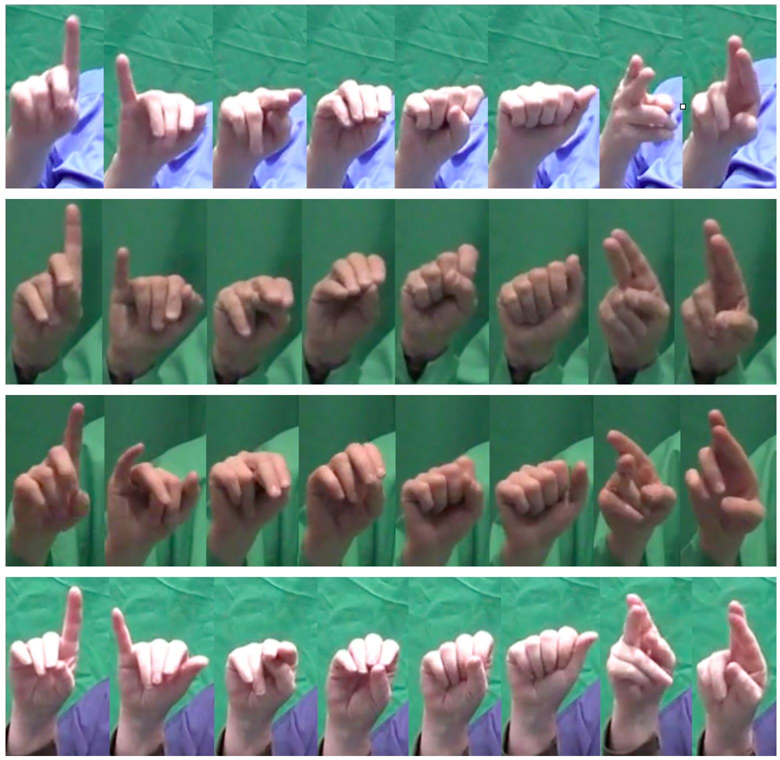


Figure 3.7: Graphic output of a search for various words with a *ur* bigram using the Google Books Ngram Viewer tool (Google, 2016).

If this generalization is accurate, it would be consistent with the hyper- and hypospeech model mentioned in Chapter 2 (Lindblom, 1990). These signers were told to fingerspell as if they were chatting with another native signer. If they assumed their interlocutor would be less familiar with words like *Mauritania* and *turquoise*, given their relative low frequency in English, Lindblom (1990) would predict that they would produce more canonical forms, only making that extra articulatory effort to make themselves understood. Higher frequency words like *nature, course*, and *source* do not require this extra effort because signers would likely assume their interlocutors are sufficiently familiar with them. The output of the ngram search appears to support this hypothesis but English word frequency alone does not capture all of these data. The word *dinosaur* is used less than *turquoise*, yet fingerspelled productions of the former included the epenthetic movement from all four Chicago signers (see Figure 3.8 and schematic notation of palm orientation in Table 3.4) but this was not the case for *turquoise.* There are three possible reasons for this. First, there might be some interaction between word frequency and word familiarity; if *dinosaur* is a more familiar word even if it is less frequent, signers would not feel the need to hypoarticulate to make themselves understood. Second, it may be that neighboring letters with non-default orientation – like the -Q- in *turquoise* – blocks the epenthetic movement (Jonathan Keane, personal communication). A final possibility is that English word frequency is an inadequate predictor for fingerspelled word frequency. No systematic work has examined this issue but it is definitely an area of research to be undertaken in the future.

Students were taught about the epenthetic movement associated with the U-R bigram based on data in my QP study, as well as naturally occurring examples of this from other sources like that in Figure 3.9. Like previous portions of the training,



(a) (b) (c) (d)

Figure 3.8: Four signers demonstrating epenthetic movement associated with the U-R bigram in the word D-I-N-O-S-A-U-R. Example (a) exhibits the most supination of the forearm. Examples (c) and (d), in addition to rotation of the forearm and deviation of the wrist, exhibit backwards crossing of the index and middle fingers. View the videos from which these still images were excerpted by clicking on the figure sub-labels above.

U-R	**Palm orientation**
(a)	neutral wrist, neutral forearm (supinated from previous hold)
(b)	slight ulnar deviation, slight supination
(c)	slight ulnar deviation, slight supination
(d)	neutral wrist, neutral forearm (supinated from previous hold)

Table 3.4: *J&L* schematic notation for Figure 3.8

students are taught, through still images accompanied by text explanation, followed by video examples, what this letter bigram looks like so that they can use this information to recognize it in the future. Future iterations of the training program should address the second way this bigram is realized non-canonically based on data from the Chicago corpus.

The U-R portion of the training, like the -Y- portion, demonstrates a way in which movement can be epenthesized to give fingerspelled utterances more characteristic shape – just as the epenthetic flexion with -Y- did – which may make certain forms, particularly those with hard-to-distinguish letter combinations, more easily recognizable. It also demonstrates that fingerspelled letters do not always represent a one-to-one correspondence with English orthographic characters since sometimes U-R is realized as a single unit (i.e., the -U- is realized in the transition before the -R-).

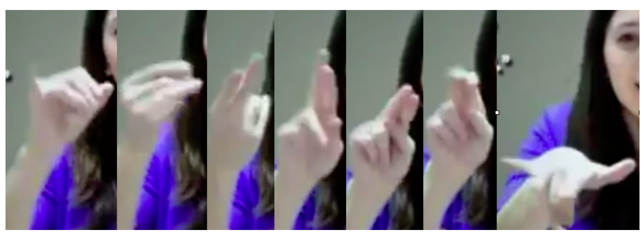


Figure 3.9: Images extracted from a native signer's production of J-O-U-R-N-E-Y in the video "Early Intervention: The Missing Link" (Benedict and Stecker, 2011). This token is the second of two productions of J-O-U-R-N-E-Y in this video and it is appreciably reduced phonologically. A form resembling the letter -O- is made in the transition from -J- to -U- and the U-R bigram is realized with the epenthetic movement described above. The -E- is made in the transition between the -N- and -Y-, and the -Y- has the expected word-final epenthetic wrist flexion. A clip with both uses of J-O-U-R-N-E-Y is available here and a clip of only the second mention, pictured above is available here.

3.2.2.4 G-H-T

The final part of the training describes another frequently occurring letter combination, G-H-T. Consider Figure 3.10. This letter combination again demonstrates the fact that there is not a one-to-one correspondence between the number of letters in an English word and number of holds in the fingerspelled version. Additionally, this is an important letter combination to include in the explicit training because it includes letters with non-default orientation of the palm, which are already more difficult for ASL learners (Keane and Geer, 2016)

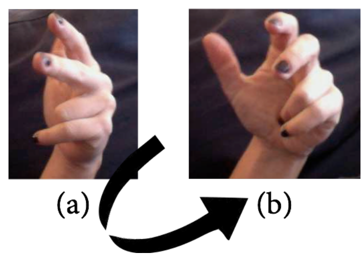


Figure 3.10: Two images of the transition between G-H and -T- in the fingerspelled word N-I-G-H-T. Image (a) shows the orientation shift (supination) required by the letters -G- and -H-. Image (b) shows outward rotation (pronation) of the forearm, or returning to the default, palm-out orientation. Both images show the anticipation of the letter -T-, which requires the index and middle finger to be separated, or abducted, to allow for insertion of the thumb between them (see Figure 1.1). Also note that in (a), the pinky remains partially extended from the previous letter -I-, while in (b) it has returned to a more flexed position.

What several of these examples demonstrate is the mismatch between the number of letters in an English word and the number of phonetic segments that may occur in fluent fingerspelling. In the case of words which include the bigram U-R, that single coarticulated form represents two English letters. Likewise, in the case of words that end in *ght*, -G- and -H- are realized together as a single segment. Thus

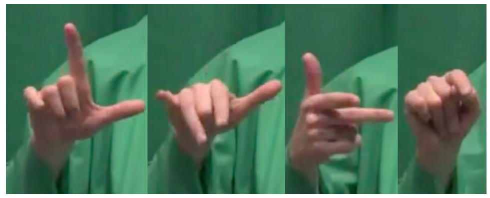


Figure 3.11: Still images extracted from a native signer's production of the second half of the word H-E-A-D-L-I-G-H-T in the Chicago corpus. This token exhibits extensive coarticulation throughout.

Figure 3.10

	HC	PalmOr
(a)	features of -I-, -G-, -H-, and -T-	neutral forearm
(b)	features of -G-, -H-, and -T-	pronation of the forearm

Figure 3.11

Letter	HC	PalmOr
-L-	-L- w/ slight pinky extension	pronation, slight wrist extension
-I-	ILY-like handshape	neutral wrist
G-H	features of G-H-T	supination, neutral wrist
-T-	-T-	pronation, slight wrist extension

Table 3.5: *J&L* schematic notation for Figures 3.10 and 3.11.

there is not a one-to-one correspondence between the number of hold segments and English letters, but students are never taught about this.

3.2.3 Characteristics of phonetic training programs

Jamieson and Morosan (1986) noted that successful training programs for second-language learners attempting to improve their ability to identify and discriminate non-native contrasts should include three features, a notion to which other researchers have also subscribed (Tremblay et al., 2001; Franceschina, 2005; Werker and Tees, 2005; McCandliss et al., 2002). These include:

1. *Acoustic context*: The training should present the relevant speech cues in an acoustic context that is appropriate for normal speech, rather than in isolation. This is also consistent with suggestions made by researchers who have studied highly-variable phonetic training (Logan et al., 1992; Pisoni et al., 1994; Iverson and Evans, 2009; Ylinen et al., 2010).

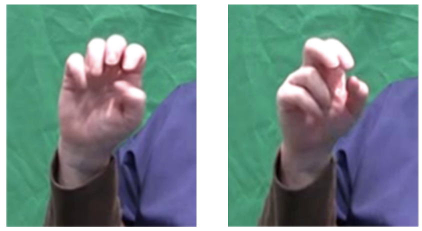
2. *Identification training*: The task should involve identification with feedback (see also Ylinen et al., 2010; Giannakopoulou et al., 2013).

3. *Acoustic uncertainty*: Training should focus attention on critically relevant cues and then introduce variability (Holt and Lotto, 2006).

The explicit training program described here has these features. Next I describe the ways in which it addresses each one.

Acoustic Context: Experimental group

This presentation provided fingerspelling in context and also presented common fingerspelling letter bigrams and, where applicable, the epenthetic movements signers produce. Specifically, participants viewed videos of fingerspelled utterances, rather than still images of the citation forms of letters, which Li and Juffs (2015) suggest may be problematic. Thus, participants were exposed to the different phonetic realizations of certain fingerspelled letters in their natural contexts. An example of this is the fingerspelled word T-E-A-C-H-E-R, which involves two different productions of the letter -E- depending on the phonetic context. Still images of these variants are given in Figure 3.12.



(a) (b)

Figure 3.12: Still images extracted from the T-E-A-C-H-E-R. In (a), the form of -E- is open but the behavior of the four digits is very similar, likely because the signer is preparing to produce the letter -A-, in which the digits all need to make the same configuration. In (b), however, the ring and pinky fingers do not appear to be selected because the signer is transitioning from the letter -H-, in which only the middle and index fingers are active, and transitioning to the letter -R-, which has the same set of selected fingers. A video of a different signer producing T-E-A-C-H-E-R is available here.

Identification training: Experimental group

The training offered feedback. For example, there were several slides in which participants were asked to view fingerspelled words. Their attention was drawn to whatever feature was being described (e.g., the -Y- with wrist flexion, the -U- and -R- combination, etc.). They were told to try to catch as many of the words as possible (these were also slowed to half speed). The next slide showed the words that were spelled on the previous slide. The video was then repeated so students had the opportunity to view words they might have missed again.

Acoustic uncertainty: Experimental group

As Keane (2014) demonstrates, cues in fingerspelling are highly variable. While some of this variation is due to individual differences, there are observable patterns across signers. For example, -E- is most likely to be open (where the tips of the digits do not make contact with the side of the thumb; refer back to Figure 3.12) when it is preceded by a completely closed letter like a -T- (Keane et al., 2013b). This may serve to maximize contrast between handshapes. There is variation in handshapes, canonical and non, as well as variation in the temporal aspects of the signal. Some signers have longer or shorter transitions, relative to the holds. Students were exposed to two signers in the training to increase variability of the input. Some video clips were produced by the experimenter, and others by a signer with whom participants had never interacted but who they did see on the pre- and post-tests.

3.3 The implicit training program: Control group

Recall that Thoryk (2010) assessed the efficacy of a curriculum designed to improve fingerspelling comprehension but that her study involved testing students who had the training versus those who had no additional training. Had she found a positive effect of the training without a control group, it would have been possible to argue that it was not the training itself that caused the improvement but rather the increase in time spent on a fingerspelling task. For this reason, in the present study, it was desirable to have an implicit training to serve as a control. This way all students, regardless of which training they receive, will have extra and, importantly, equal, time on a fingerspelling task. A positive result in the training studies then means it is a result of explicit training and not an artifact of having more time interacting with a fingerspelling task.

Students in the control group received training in fingerspelling, but crucially, this training did not bring their attention to the types of segments in fingerspelling nor to the fact that fingerspelled items can take on a specific shape, particularly when certain and frequent bigrams are present. A specific rule was not explained to participants, nor could they infer one based on the training Dekeyser (2003).

The control group's training focused on prescriptively correct formation of the citation form of each of the letters in the manual alphabet, which students all learned at the start of their ASL classes. This training included still images of each of the manual letters, except for -J- and -Z-, which were presented with short video clips since their production involves movement. In addition, participants were reminded that while most letters are produced with the palm facing away from them, there are some exceptions to this generalization. Their training included images of two angles of letters produced with non-default palm orientation; these are presented in Figure 3.13.

Figure 3.13: Still images of the letters -G-, -H-, -P-, and -Q-. Unlike the majority of fingerspelled letters, these are not produced with the palm facing outward. For each letter, the images alternate between a front (from the view of the perceiver) and side views. It should be noted that in some dialects of ASL, productions of -G- and -H- with a a neutral or slightly extended wrist (orientation in which the index finger points away from the signer and the back of the thumb faces the signer's midline) are acceptable, but this variant is uncommon in Texas where these students are learning.

Students completed the review of fingerspelling production with much of the same media content as the explicit training group however, they remained naïve to the structure of, and types of coarticulation in fingerspelling, which was the focus of the explicit training. For example, all of the same videos included in the explicit training also appear in the implicit training, but students are not asked to attend to one particular aspect of the video. An example of differences in how the same media is presented in the two trainings is presented in Table 3.6. The training concluded with reminders of how to produce double letters in fingerspelling, following Smith et al. (2008) and that fingerspelling should be produced smoothly and without jerking movements. This training lasted approximately 30-40 minutes.

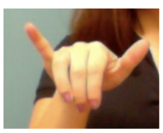
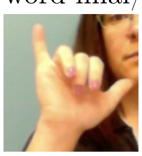
Explicit	**Implicit**
Slide 13 -Y- •The letter -Y-, when produced in isolation, has normal orientation and bending at the wrist. •But, often times, when it's in the middle or end of a word, signers will add a bend at the wrist to help this letter stand out. •Let's look at some examples	
Slide 14 -Y-   word final/internal: BOY/HIMALAYA  word final: YOSEMITE	Slide 23 Here are some other words
Slide 15 [video of the fingerspelled word BOY, OYSTER, OLYMPICS, HIMALAYA and YOSEMITE]	Slide 24 [video of the fingerspelled word BOY, OYSTER, OLYMPICS, HIMALAYA and YOSEMITE]

Table 3.6: Comparison of slides with the same video in the Explicit and Implicit training programs. For actual representation of slides, refer to Appendices A and B.

The implicit training included (most of) the features Jamieson and Morosan (1986) proposed:

Acoustic Context: Control group

The implicit training involved delivery of a mixed-media presentation including fingerspelling in context.

Identification training: Control group

The implicit training slide presentation, just as the explicit training did, offered feedback. For example, there were several slides in which participants were asked to view fingerspelled words. While their attention was not drawn to whatever feature was demonstrated in the videos (e.g., the -Y- with wrist flexion, the -U- and -R- combination, etc.), the same media content was used in this training program. Participants were told to try to catch as many of the words as possible (these were also slowed to half speed). The next slide showed the words that had been spelled on the previous slide. The video was then repeated so students would have the opportunity to view words they might have missed again.

Acoustic uncertainty: Control group

One important difference between the training of the treatment group and that of the control is that participants' attention could not be brought to the critically relevant cues in the transitions in fingerspelling. However, this group was still exposed to variability. The training featured videos produced by the experimenter as well as another signer with whom the students had not interacted, though they had seen her in the pre-test.

3.4 Summary of training programs

The goal of the training programs I have designed is that they should be as similar as possible, except for the obvious ways in which they have to differ, namely in explicit versus implicit explication of fingerspelling. Below is a summary of the ways in which the training programs are similar and different.

1. Both trainings have the same number of slides (39).

2. Both trainings have the same number of introduction slides (2). One of the introductory slides is identical in both programs.

3. Both trainings have the same number of slides explaining the goals of the program (5). For the implicit training, there are five slides detailing the citation form of each letter in the manual alphabet and for the explicit training group there are five slides explaining the structure of fingerspelling (holds versus transitions).

4. One slide in each of the presentations has a graphic with still images of different segments in fingerspelling.

5. All of the videos used in the experimental group slides are also used in the control group slides.

6. There are some videos used in the control group slides not used in the experimental group slides (for explaining production of double letters), but these are balanced out by slides explaining variability of production in the treatment group slides.

7. Both trainings have the same number of summary slides (2).

8. Both trainings have the same slide at the end closing the presentation (1).

9. Both trainings include feedback; videos are shown, then answers presented, then video is repeated.

In summary, the most crucial difference between the training programs is the contextualization of information in the explicit training. Students' attention is brought to aspects of fingerspelling structure and phonetic variation which they can then consciously consider. Schmidt (2001) argues this type of knowledge is an important aspect of second-language development. Students are not only exposed to variation in phonetic cues in fingerspelling, but are also made aware of patterns of variation. With this information, as Saito (2011) found for Japanese learners of English, for instance, ASL-learners should be better able to appreciate the information they are seeing when they perceive fingerspelling, rather than focusing only on the hold segments, which is what Geer and Keane (2014) and Keane and Geer (2016) found students tend to do.

This chapter detailed the development of the explicit training program, which is what is truly being assessed in the subsequent chapters, but also the training that was designed as a control. The latter was developed so that improvement in fingerspelling comprehension on students' post-tests can be attributed to the type of training they received and not be the result of more time spent on a fingerspelling task. To this end, the training programs had to be as similar as possible, except for the obvious features on which they had to differ. The training program developed here differs from that assessed by Thoryk (2010) because it was developed based on empirical research findings, as well as trends in fingerspelling production evidenced across multiple data sets. In addition, the notion of a control training is different from Thoryk's study because hers offered no control training. There are additional types of phonetic variation which could have been included in the explicit training but it was most desirable to keep both trainings as equal in length as possible. Future trainings could incorporate instruction on these phonetic differences as well. I will discuss these in Chapter 6.

Chapter 4

Training Study 1

This chapter details a pilot investigation of a training program designed to improve fingerspelling comprehension in third-semester ASL students through explicit phonetic instruction. This chapter begins with a brief overview of findings from studies on fingerspelling comprehension, as well as those of explicit phonetic instruction in L2 teaching, which I reviewed in detail in Chapter 2. Taken together, these motivate the present experiment.

4.1 Introduction

This experiment builds on previous work that examined cues relevant for successful fingerspelling comprehension, which is a difficult task even for experienced signers (Hanson, 1981). Schwarz (2000) showed that transitions were in fact important for successful fingerspelling comprehension but this was due, in part, on the position of a masked letter in the word. A masked hold in the middle of the word, for example, had the least impact on comprehension scores, while a masked letter posture in initial or final position had greater impact. One potential explanation Schwarz offers for this is that masked holds in the middle of the word were shorter than those at the end. This study demonstrated that transitions do not provide all of the necessary information to understand fingerspelled words but skilled signers are able to extract some information from transitions surrounding hold segments. Schwarz suggested future work should examine other cues to comprehension in fingerspelling and whether some might be more useful than others in leading to successful comprehension. Geer and Keane (2014) showed that students acquiring ASL perform better when provided with the hold portion of the fingerspelling signal as compared to the transition portion though this was not because the transition portion is longer than the hold portions. Keane and Geer (2016) analyzed potential sources of errors in comprehension. The purpose of the present study is to test an explicit training program developed to assist learners in becoming aware of additional cues in the fingerspelling stream which they can exploit for successful comprehension. This is made possible with the fingerspelling corpus collected and annotated by Keane and colleagues (Keane, 2014; Keane et al., 2013c, 2015, 2013a). Explicit training in spoken foreign language teaching has been effective in helping students improve perception and in some cases production as well (Ylinen et al., 2010; Giannakopoulou et al., 2013; Saito, 2011), but these effects have not been demonstrated cross-modally.

The goal of this study is to answer the following research questions.

1. Will students who receive explicit training improve more than students receiving implicit fingerspelling training?

2. Will explicit training have more, less, or equal effect on fingerspelling comprehension in the two experimental conditions – holds-only versus transitions-only – and the control conditions?

Use of explicit instruction in my own classroom with ASL students in their second semester of learning has resulted in improved scores on fingerspelling quizzes. In addition, a meta-analysis of L2 teaching techniques showed that explicit instruction results in greater gains than implicit instruction (Norris and Ortega, 2000). Thus, I hypothesize that the group that receives explicit phonetic instruction on fingerspelling will improve more than students in the implicit training group. With respect to the second question, my hypothesis is that that explicit phonetic instruction will help participants improve across conditions, but most especially in the *transitions-only* condition since that is where they struggle the most currently and the training draws their attention to this part of the signal.

4.2 Methods

Students from the ASL program at The University of Texas at Austin participated in this study in exchange for course credit. More information about the participants and the approach used are detailed below.

4.2.1 Participants

Eighteen ASL students in their third-semester of language-learning participated in this experiment (f = 14). The class was split into two groups; one received the explicit fingerspelling training, while the other received the implicit training. Groups were balanced for grades received in students' highest completed level of ASL at the time of study. Table 4.1 presents more group characteristics.

As this table demonstrates, groups were not only balanced with respect to grades received in their previous ASL course, but also with respect to age at the

Characteristic	*Explicit training*	*Implicit training*
Gender	f = 8, m = 1	f = 6, m = 3
ASL 2 grade	A = 3, A- = 2, B+ = 3, B = 1	A = 3, A- = 2, B+ = 3, B = 1
ASL required for major	2	1
Languages other than English	Spanish	
Avg age of ASL acquisition	22	21
Avg age at time of study	24	24
Hearing status	hearing = 8, hh = 1	hearing = 9

Table 4.1: Participant characteristics by group

time of study, age of acquisition, gender, hearing status, and language background.[1] Students also reported no vision issues which result in difficulty seeing on a computer screen.

4.2.2 Delivery

Participants entered a unique study identification number to complete a pre- and post-test in *Qualtrics*. These tests included the same content and basic design as those used in Keane and Geer (2016), but did not use the program PsychoPy (Peirce, 2007, 2009), which sometimes has technical glitches in the replaying of video content. As such, it was desirable to find a new way to deliver the experiment. Additionally, participants had to be run one-by-one in Geer and Keane (2014) and Keane and Geer (2016), which was not ideal given the time constraints on this experiment. Qualtrics allowed for experiment delivery with minimal complications and allowed

[1]One student in the explicit training group indicated that they knew "some Spanish," which is why it is listed in the table, but no other students indicated having knowledge of/proficiency in any other language. All students are native speakers of English.

participants to complete it in the comfort of their own homes, if they chose, or in some other location at their leisure.

The training program – explicit and implicit, see Chapter 3 for a full description – was delivered via mixed media slide presentation in Keynote. Because this program only runs on the most current version of Apple operating systems, participants who did not own apple computers or didn't have the most recent software, had to complete the training programs in the ASL Teaching Lab housed in the Department of Linguistics. The training was self-paced and students could move forward and backward through the slides at their leisure. The training lasted 30-40 minutes.

4.2.3 Stimuli

Video stimuli for this project consisted of fingerspelling video clips from the corpus collected and annotated by Keane and colleagues (Keane, 2014; Keane et al., 2013c, 2015, 2013a). In their corpus, Keane and colleagues identified stable hand configurations, which they termed *apogees* as periods in which the velocity of the hand was zero or approached zero (see §3.2.2 of Keane, 2014, for more detailed information about segment identification in this corpus). In other words, the portion of the signal where the hand is as still as possible is the hold portion. The portions in between held postures are transition segments. Raw video footage was modified in the following ways. Hyperlinks to video examples are provided.

- slowed to half-speed (all: see F-A-C-E and P-A-R-T for two examples of unmasked stimuli)

- black screen masks inserted into the transition portions of each of the clips to create the *holds-only* condition (30 items: see F-A-C-E-holds and P-A-R-T-holds for two examples of holds-only stimuli)

- black screen masks inserted into the hold portions of each of the clips to create the *transitions-only* condition (30 items: see F-A-C-E-trans and P-A-R-T-trans for two examples of transitions-only stimuli)

The stimuli were all slowed to half speed for this project to avoid a floor-effect. Before data collection for the study reported in Geer and Keane (2014) began in earnest, several students volunteered to test project stimuli. At normal speed, students were unable to comprehend fingerspelled stimuli, even without masking. To combat this issue but still examine relevant cues in the fingerspelling stream, video clips were slowed to facilitate student testing. Crucially, half-speed stimuli retain their timing properties. For example, consider Figure 4.1. In this particular token, the hold portions are longer than the transition portions. Even when the item is slowed to half speed, this remains true. Instead of -C- being presented for 149ms, however, it would be presented for double that, or 298ms. This is important because previous work asserted that the reason transitions were most important for fingerspelling comprehension is because they are temporally longer (Wilcox, 1992). As Keane and colleagues have shown, this is not always the case and in fact, as this token exemplifies, sometimes the duration of the holds is greater than that of the transitions (Keane, 2014; Keane et al., 2013c, 2015).

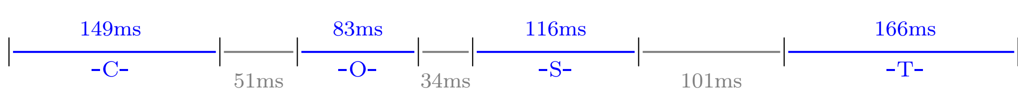


Figure 4.1: Timeline depicting the proportion of time spent in transition and hold segments of the fingerspelled utterance C-O-S-T. Blue segments, indicated with a letter label, represent holds and gray segments represent transitions. For this particular token, holds are appreciably longer than transition segments. The average duration of hold segments in this token is 128.5ms and the average duration for transition segments is 62ms.

The pre- and post-tests included a total of 94 video clips. To generate this list, common four- to six-letter words were extracted from the CELEX database (Baayan et al., 1995). Of these, four served as practice items for participants to familiarize themselves with the task before it actually began. The first full block of 15 tokens (allClearA) had no masking. These served as control items. The second full block consisted of 30 hold only items and the third full block had 30 transition only items. The final block consisted of another 15 control items (allClearB).

4.2.4 Timeline

This experiment was conducted during a summer session, which lasts approximately five weeks. To ensure that all data were collected within this short time frame, but also considering that students might be busy with other classes, work, or other summer events, participants were given one full week to complete the pre-test. During this time, they did not have access to the training they were to complete at a later time. Students knew to which group they had been assigned – explicit or implicit – but remained naïve to the purpose of the experiment and the differences in the training they would receive (they knew the training programs as 'A' and 'B'). In the week following the pre-test, students gained access to their respective training program and had that week to complete it. In the third full week of summer school, two weeks after beginning the pre-test, students were granted access to the post-test. At this point, they no longer had access to the training programs and thus could not go back and view them. From start to finish, the experiment was conducted over a three week period.

4.3 Results

This experiment explores two main research questions.

1. Will students who receive the explicit fingerspelling training improve more than students receiving the implicit training?

2. Will the explicit training have more, less, or equal effect on fingerspelling comprehension in the two experimental conditions and the control conditions?

Based on research on the role of explicit training in second-language teaching (e.g., Saito, 2007, 2011; Norris and Ortega, 2000), I predict that students who receive the explicit training will improve more on the post-test than students who receive the implicit training. Furthermore, because the explicit training draws participants' attention to the transition portion of fingerspelling – segments to which they had likely assigned little weight – I predict they will improve more in that particular condition from pre- to post-test. Giannakopoulou et al. (2013) showed that when forced to attend to cues for which participants had assigned a low weight, participants are able to re-weight cues and improve phoneme discrimination.

Responses in this experiment were counted as *correct* or *incorrect*. To be counted as *correct*, the typed response participants provided had to match the target word exactly. For example, if the fingerspelled target word were E-F-F-E-C-T, the typed response would have to be *effect*. Responses which were close – off by only a letter or two – were counted as *incorrect*. Table 4.2 presents the mean proportion of correct responses in each condition, for each test, and for each group of participants. Several trends can be noted in these data.

- Performance overall was poor. On the pre-test, scores averaged approximately 37% across all conditions.

		training	
block	testType	implicit mean(SD)	explicit mean(SD)
allClearA	pretest	0.305 (0.460)	0.392 (0.488)
	posttest	0.305 (0.460)	0.657 (0.475)
holdsOnly	pretest	0.419 (0.493)	0.421 (0.494)
	posttest	0.448 (0.497)	0.605 (0.489)
transitionsOnly	pretest	0.186 (0.389)	0.188 (0.390)
	posttest	0.238 (0.426)	0.290 (0.454)
allClearB	pretest	0.562 (0.496)	0.558 (0.497)
	posttest	0.476 (0.499)	0.667 (0.471)

Table 4.2: Table of mean proportion of correct responses and standard deviations by test type, condition (block), and training for Experiment 1.

- Performance is better in the holds-only condition versus the transitions-only condition (for both groups of participants). Average performance for holds-only was in the 40%-accuracy range, while average performance for transitions only was below 20%.

- Performance is better in the allClearB condition than the other conditions (for both groups of participants). In allClearA, average performance on the pre-test was 35% while performance in allClearB was 56%.

- Participants in the implicit group performed equally on the pre- and post-tests across conditions. For example, in the holds-only condition, students in the implicit training group scored 42% on the pre-test and around 45% on the post-test.

- Participants in the explicit group improved from pre- to post-test. For example, scores in the holds-only condition rose from 42% on the pre-test to 60% on the post-test.

Data from all 18 participants were submitted to a mixed effects logistic regression model computed in `R` (RStudio *v. 0.99.48*, R Core Team, 2013) with the package `lme4` (*v1.1-7*, Bates et al., 2015). These are also known as hierarchical or multi-level models. Here, I use the term "mixed effects." Before reporting the findings, I describe why this type of model was chosen, how the model is interpreted, and what the results from this model indicate. For additional reading on use of logit models in the social sciences, see Jaeger (2008).

Because the responses in this experiment were categorized as *correct* or *incorrect*, these values were represented by the numbers 1 and 0, respectively. The predictions from this model represent the odds of a correct answer. In a linear regression model, predictions could potentially yield values greater than 1 or less than 0. This is problematic because "greater than 100% probability of a correct answer" doesn't make sense, nor does "less than 0% probability of a correct answer". A logistic regression model constrains predictions to the range of 0 to 100%.

The significant results from the mixed-effects model can be found in Table 4.3. The full model output is available in Appendix D. The text that follows will help the reader interpret this table. Visualizations are also available and will be detailed subsequently. The names in the table follow this schema: the first part of the name is the variable and the second part is the non-reference level. Interactions are represented with a colon in the name.

	coefficient (standard error)
(Intercept)	-1.26 $(0.53)^{*}$
testTypePostTest:groupA	1.68 $(0.68)^{*}$

$^{*}p < 0.05$

Table 4.3: Significant results from the mixed effects logistic regression coefficient estimates and standard errors. "GroupA" refers to the group that received the explicit training.

Again, this model has the outcome as correct or not which means it is evaluating whether responses match what word was actually fingerspelled. The predictors input into the statistical model with the function `glmer()` are `condition` (allclearA, holdsOnly, transOnly, allclearB), `testtype` (pre- or post-), and `group` (explicit-A, implicit-B) and all of their interactions. The intercept varies based on several grouping variables. These include number in the test, the word they responded to, and subject. Additionally the effects of condition and test-type were allowed to vary by word and by subject. In Table 4.3, a positive value for a predictor indicates that that predictor is correlated with relatively more correct answers, and a negative value for a predictor correspondingly correlates with relatively fewer correct answers. The magnitude and direction corresponds to the relative likelihood of a correct answer. Thus, a bigger positive number means the answers are more likely to match, and a bigger negative number means the answers are less likely to match.

The mixed effects model requires that, for each of the predictors, one level be set as the reference level. This means that the interpretation of Table 4.3 depends on understanding which level is set as the reference. It may also be useful to understand why each of these reference levels was selected. Please refer to Table 4.4.

For the test-type predictor, the pre-test is the reference level because we are interested in how much change there is from pre- to post-test. This means that if participants improve from pre- to post-test – as the hypothesis predicts they will – we

predictor	number of levels	reference level
test-type	2	pre-test
group	2	group B (implicit training)
condition (block)	4	allClearA

Table 4.4: Table of predictor variables and their reference levels

should see a positive number, or a positive number of greater magnitude than in the pre-test. For the group predictor, the group of students who received the implicit training, called group B here, is the reference level because we were interested in learning whether group A, or the group which received the explicit training will diverge from the assumed baseline group B represents. The hypothesis posits that the group that receives explicit training will improve more than the implicit group, which supports the decision to set the implicit group as the reference level for this predictor. The condition predictor has four levels; allClearA is the reference level. Previous work has shown that students perform significantly better in the holds-only versus transitions-only condition. We would predict that this would be true again, however it makes more sense to use one of the all-clear conditions as the reference level because they involve unmodified stimuli. Positive values represent performance better than the reference level and negative values represent performance worse than on the reference level. We would expect then, based on Geer and Keane (2014) and Keane and Geer (2016), that values would be equal or positive in the holds-only condition and negative in the transitions-only condition.

To interpret any values that meet significance, again refer to the reference level for that predictor. If an interaction is significant, it means we would expect a stronger (or weaker, depending on the sign of the interaction effect and the sign of the predictor effects) response than either variable on its own. Additionally, when a value is significant, it means that the effect size is big enough to overcome the noise of the variability in the data. This point will be important to remember in the discussion section. The intercept represents the prediction for all reference levels; so in this model, that value is the prediction for group B in the pre-test in the allClearA condition. This value is listed as significant in the table. The significance indicates that, because the value is negative, overall performance in this group was poor and correct answers were provided less than 50% of the time, a fact which is visible also in Figure 4.2. This has no bearing on either research question so the intercept will not be discussed further, but it is worth nothing that this demonstrates the extent to which students are still struggling with fingerspelling comprehension.

The only effect that is significant in this model is the interaction of training type and test-type. Specifically, the students with explicit training, in the post-test, did better than any other group by a statistically significant margin ($p < 0.05$). This finding speaks specifically to the first research question. Students tended to perform better in the holds-only condition, as compared to the transitions-only condition, but the difference between the two did not reach significance. The trend is in the same direction Geer and Keane (2014) observed, and it is possible these trends could become significant with a larger number of participants, so this is something to anticipate in the second training study, detailed in the next chapter. With respect to the second research question, this model suggests the training had roughly equal impact on all conditions, but performance is still weakest in the transitions-only condition.

The box plot presented in Figure 4.2 illustrates the basic findings in this experiment which, in addition to Table 4.3, speak to the first research question. Here, visually, we can see that participants in both groups performed similarly on the pre-test, correctly identifying approximately 37% of fingerspelled items. The performance of participants in the implicit training group remained the same on the post-test. Those in the explicit training group improved significantly suggesting that the explicit training was effective in improving fingerspelling comprehension scores in student learners.

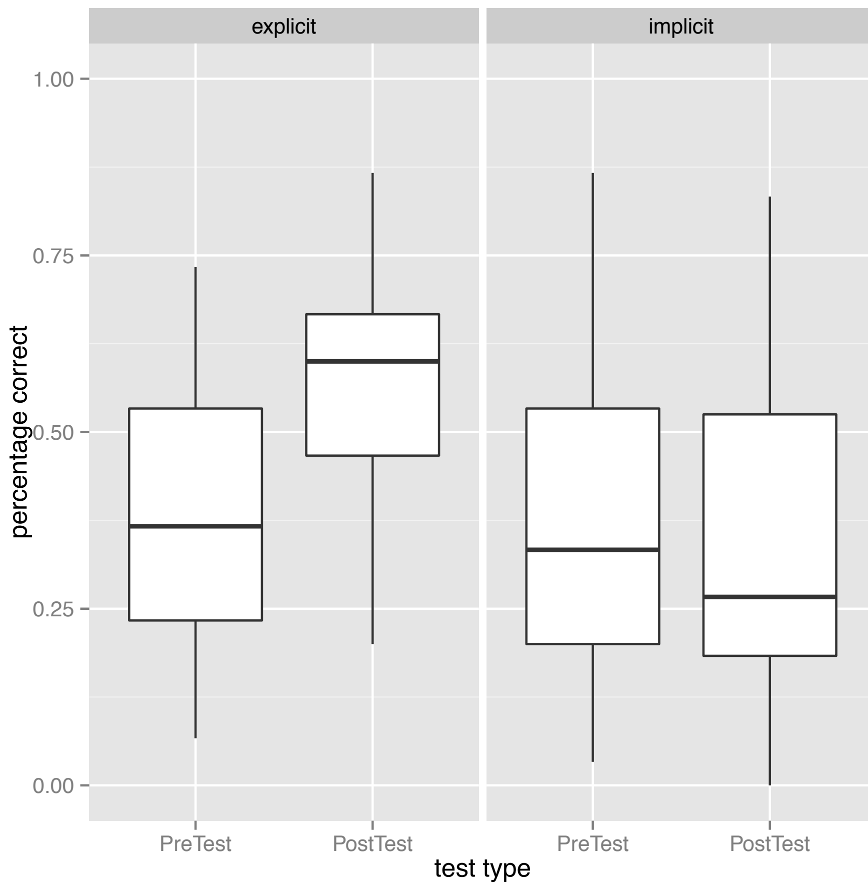


Figure 4.2: Box plot showing the percentage correct broken down by test-type (pre or post) and training group (explicit or implicit). The lines in the center of the boxes are the median, the boxes contain the inner quartile range, the whiskers contain 95% of the data observed. The difference between groups on the post-test is statistically significant.

The box plot presented in Figure 4.3 speaks to some of the trends mentioned above, but which were not statistically significant. One trend visible in in this plot, is that all participants performed better in the holds-only versus transitions-only condition. Based on previous works (Geer and Keane, 2014; Keane and Geer, 2016), we would have expected this difference to reach significance, but here it did not, perhaps due to the number of participants in each group and thus a lack of statistical power.

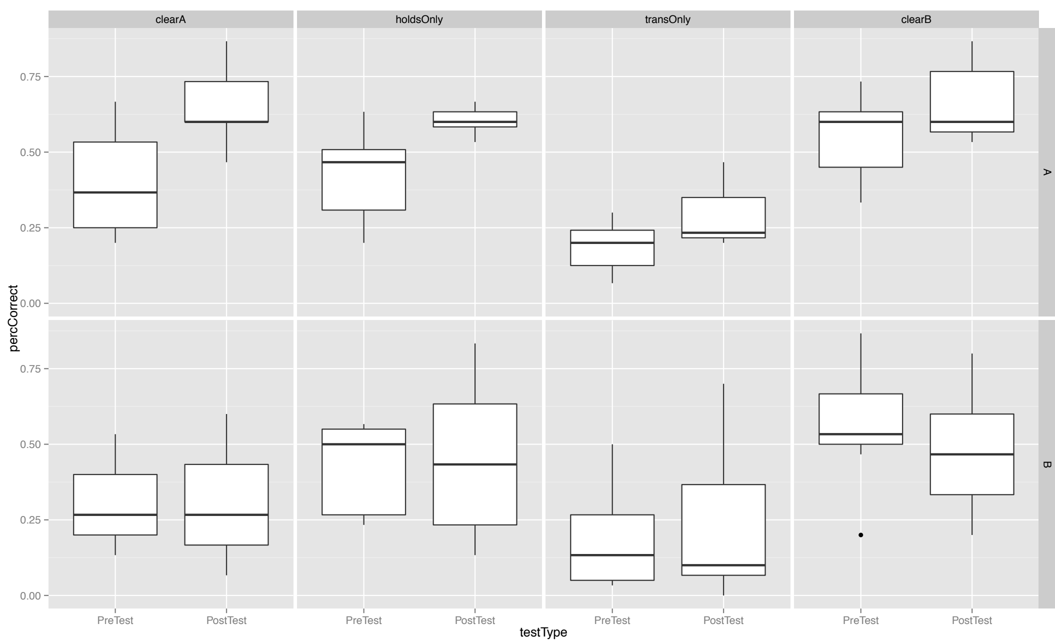


Figure 4.3: Box plot showing the percentage correct broken down by test-type (pre or post), condition (clearA, holdsOnly, transOnly, clearB), and training group (A = explicit or B = implicit). The lines in the center of the boxes are the median, the boxes contain the inner quartile range, the whiskers contain 95% of the data observed.

There are several noteworthy features of this figure. The first is consistent with what is predicted based on Figure 4.2, namely, that the explicit training group showed improvement from pre- to post-test, while the implicit training group did not. Examining the figure more closely, other interesting observations can be made. Notice that, in general, not only did the participants in the explicit training group improve from pre- to post-test, but they performed more similarly to each other, indicated by the smaller boxes and/or shorter whiskers, than the participants in the implicit training group. Finally, notice that, while explicit training group participants improved across conditions, they still struggled the most with the transitions-only condition.

4.4 Discussion

The goal of this study was to determine whether explicit phonetic instruction would benefit adult students acquiring ASL as a second language, with a particular focus on fingerspelling comprehension. Prior work suggests that part of their challenge with understanding fingerspelling could be related to incorrect cue-weighting (Geer and Keane, 2014; Keane and Geer, 2016). Based on these works and others which have examined explicit phonetic instruction in spoken language-learning, the study examined two research questions: (1) Can explicit phonetic instruction benefit ASL-learners on a fingerspelling comprehension task, and (2) Will it impact fingerspelling comprehension equally in various conditions?

In order to control for language proficiency in some way without administering a standardized test for ASL proficiency (of which there is none for L2 learners), grades in participants' previous ASL course were used as a proxy. The results show that this was a fairly good measure as performance on the pretest was roughly equal across groups.

With respect to the first question, the results indicate that explicit knowledge of fingerspelling structure and phonetic variation benefits language-learners. In addition to improved performance by a statistically significant margin, participants report relief in having more tools to tackle fingerspelling comprehension generally. They liken it to the difference between only knowing how to read print, but being forced to read cursive. They also noted the value of understanding the types of variation they might encounter in fingerspelling. These results are encouraging and suggest that ASL curricula should incorporate this type of instruction.

The results that bear on the second question indicate that the training was equally effective across conditions. This is indicated by a lack of a significant three-way interaction between group, test-type, and condition (refer to Table 4.3). In some respects this is discouraging because I hypothesized that bringing students' attention to the information they can exploit in the transition segments would help them to improve on this condition in particular, but this was not borne out. There are several reasons which could explain this lack of a finding. It is possible there was simply too much noise that the small data set could not overcome and a significant effect went undetected. Evidence for this supposition comes from the fact that participants *did* improve in this condition, just not enough to reach significance more than in other conditions. An additional explanation could stem from the lack of opportunity to train more on these synthesized stimuli, which could force participants to attend to the cues that are available, even though they are not the cues they prefer. This would look very much like the study done by Giannakopoulou et al. (2013), which showed that participants who train on both natural and synthesized stimuli which eliminate the cue on which learners are over dependent, is more effective than natural stimuli alone. The current training program used only natural stimuli.

As I mentioned earlier, I met with study participants after all data had been collected to discuss their experience in the experiment. I told them I would be doing a follow-up study in the near future and would be keen to learn what they thought of the study as a whole, but the training programs in particular. All students indicated they felt their training was beneficial to them. Students in the explicit training group said they appreciated being made aware of the "inner workings" of fingerspelling. They felt it made them better prepared to appreciate fingerspelling as a whole, rather than letter-for-letter. Such comments are consistent with why I predicted the explicit training would yield significant results. Students benefited from the conscious knowledge of various aspects of the target language (Schmidt, 2001) which are very different from their native language, particularly since their new language is in a new modality

This remark that students feel better prepared to see fingerspelling as a whole rather than letter-by-letter is interesting because most teachers – at least at The University of Texas – instruct students to "sound words out" rather than naming each letter in their heads. After all, it is possible to correctly identify a long string of letters, but not understand the whole word. The goal of this instruction is to encourage them to see the whole word and not each of the letters, but it seems this specific instruction is ineffective. So, while we tell students to "sound out" fingerspelled words, it would seem we are not giving them the tools to learn how to do this. Worse still, as Li and Juffs (2015) suggested, how we teach students could be hindering their ability to see the forest (whole words) instead of the trees (individual letters). These students said this training helped to shed light on that. In addition, students expressed frustration with variation they encountered in fingerspelling. "It's hard when one signer produces [some fingerspelled letter] like this [showing some variant of the letter], while other signers do it like that [showing some other variant of the letter].” Arming them with knowledge of the types of variation they might encounter helped them feel more secure in tackling fingerspelling comprehension tasks.

Students in the implicit group also had positive comments about the training. They were grateful to have had a “back to basics” review of fingerspelling production. They said it was helpful to see still images of each of the letter and have them interspersed with videos of fingerspelling production. Participants who received this training indicated it took 30-40 minutes to complete. Students in both groups said they felt their scores from pre- to post-test improved. Those in the implicit training group were shocked to learn that their scores had not, in fact, improved.

4.5 Improvements for follow-up study

While the results of this small study are encouraging, there are several additional questions which could be asked with a larger data set. A repeat study would also allow a test of whether the results presented here are replicable.

Previous work, namely Keane and Geer (2016), showed that 63 students performed worse on fingerspelled words that contain letters with non-default orientation. Because the present study had only 18 participants, it is likely there was simply not enough statistical power to find this result even if the effect is there. Further testing with a larger subject pool would allow this question to be probed. In addition, it would be interesting to see how long the effects of this training persist. This was impossible to test in the present study given the nature of summer school courses, which run only five weeks. A repeated study conducted during the long semester affords repeated post-testing to determine whether the effects persist or were the result of taking the post-test only a very short time after completing the training.

In addition to the other questions that can be asked with a follow-up study, there are several modifications to the study design that allow for better testing and a more user-friendly experience for participants. The changes to experimental methodology will be detailed in Chapter 5.

Chapter 5

Training Study 2

This chapter details a follow-up, larger-scale study of fingerspelling comprehension in third-semester ASL students. The primary goal of this experiment, which uses the same training program implemented in the pilot project reported in Chapter 4, is to replicate those results with a larger pool of participants. In addition, the number of participants in this larger project allows additional research questions to be asked. Namely, Keane and Geer (2016) found that comprehension errors are predicted strongly by the presence of letters that have non-default palm orientation. That is, letters in which the palm faces inward, as opposed to the canonical outward-facing position. This finding has yet to be replicated, nor is it known whether the training program may ameliorate this issue. This experiment included several changes to the methodology in an effort to make the results more reliable and also to improve participant experience. Here, I begin with a summary of the findings from the pilot study to provide a starting point for the explication of the study reported in this chapter. For information on previous work which motivated this project, refer back to Chapter 2.

5.1 Introduction

Several studies demonstrate that fingerspelling comprehension is a challenging task for skilled signers who have been using the language for some time as well student learners who are new to using ASL (Hanson, 1981; Schwarz, 2000; Geer and Keane, 2014; Keane and Geer, 2016). With respect to student-learners, it is unclear why they should struggle with this aspect of language acquisition more than others, particularly because fingerspelling is a representation of English orthography, with which college-level students have ample experience.

The study reported in Chapter 4 examined whether student learners would benefit from a fingerspelling comprehension training program which drew their attention to several key aspects of fingerspelling production as has been done in several studies of phonetic instruction for English-learners (Iverson et al., 2005; Ylinen et al., 2010; Giannakopoulou et al., 2013; Saito, 2007, 2011, among others). Students learned about the structure of fingerspelling and how it can be divided into segments during which the signer *holds* a static posture and periods during which a signer *transitions* from one posture to the next. They also learned that sometimes in rapid fingerspelling, there are characteristic ways in which the hold portion of fingerspelled utterances may vary depending on the phonetic context. That is, some letters influence others to take a non-canonical configuration. This may result in a lack of a one-to-one correspondence between English orthographic characters and fingerspelled letters. That is, the length of the orthographic string is not equal to the number of holds in the fingerspelled string. In addition to learning about non-canonical hand configurations, students are made aware that sometimes the overall shape, or movement contour formed by transitional segments in the fingerspelling signal may prove useful in helping them to make better guesses about what word might have been produced. This training program was termed *explicit* because it involved clear explication of phonetic variation in fingerspelling, as well as information about fingerspelling structure. This has been shown to be most effective in foreign language teaching (Norris and Ortega, 2000). To serve as a control, half the participants received *implicit* training, which provided a general overview of how fingerspelling should be produced, but did not explicate any rules about structure and/or variation such that students could even infer a rule (Dekeyser, 2003). This program mirrored the way in which fingerspelling is generally taught in L2 ASL classrooms following Smith et al. (2008).

Participants who received the explicit training performed significantly better from their pre- to post-test, and significantly better than the group that received general training on fingerspelling. These results suggest that students benefit from explicit instruction in phonetic variation and that knowledge of fingerspelling structure allows them to improve their performance.

While the pilot project offered encouraging results, there are several reasons to undertake a second, larger-scale study. Eighteen students enrolled in ASL 3 over the summer and I was able to test all of them. However, anecdotally, the demographics of students who take language courses over the summer are often different than those who take these courses in the long semesters. For example, there are often many student athletes who take language courses in the summer because their athletic participation would cause them to miss too many class sessions in the long semester. To eliminate this potential confound, and also to test a larger and more representative group of ASL students, the present chapter details a follow-up study meant to replicate results from the first study.

This chapter proceeds in the following manner. First, I detail the ways the methodology employed in this project changed from the previous study. Next, I present the results along with a discussion. I conclude with closing remarks about the broader impacts of these studies and suggestions for future studies in this line of work.

5.2 Methods

5.2.1 Participants

Eighty ASL students in their third semester of language-learning participated in this experiment in exchange for course credit. Students were divided among four classes. Two of these were taught by instructor Lila[1] and two were taught by instructor Stephen, who also taught the class tested in the pilot experiment. Within each class, students were divided into two groups based on the grade they received in their previous ASL course, as a proxy for language proficiency, as was done in Chapter 4. This division also led to fairly good balance in age and gender distribution as well. Characteristics of participants in each class and each group are presented in Tables 5.1-5.4.

Characteristic	*Explicit training*	*Implicit training*
Gender	f = 8, m = 3	f = 9, m = 3
ASL 2 grade	A = 2, A- = 4, B+ = 3, B = 2, unknown = 1	A = 3, A- = 4, B+ = 3, B = 2, B- = 1
Hearing status	hearing = 10, hh, = 1 deaf = 1	hearing = 12

Table 5.1: Participant characteristics from Stephen's first class by group.

[1]The names given here are pseudonyms

Characteristic	*Explicit training*	*Implicit training*
Gender	f = 11, m = 2	f = 9, m = 2
ASL 2 grade	A = 6, A- = 2, B+ = 2, B = 2	A = 5, A- = 3, B+ = 2, B = 1
Hearing status	hearing = 12, hh = 1	hearing = 11

Table 5.2: Participant characteristics from Stephen's second class by group.

Characteristic	*Explicit training*	*Implicit training*
Gender	f = 9, m = 1	f = 8, m = 2
ASL 2 grade	A = 3, A- = 4, B+ = 1, B = 1, B- = 1	A = 4, A- = 4, B+ = 1, B = 1
Hearing status	hearing = 10	hearing = 10

Table 5.3: Participant characteristics from Lila's first class by group.

In addition to balance within each class, participants in the explicit and implicit training groups were balanced across all students. Table 5.5 presents information for all study participants.[2]

5.2.2 Delivery

A web-based system[3] delivered this experiment's pre-, and two post-tests (cf experiment reported in Chapter 4 which was delivered using *Qualtrics*). What these tests entailed is detailed in §5.2.3. This change afforded several advantages over *Qualtrics*. With this system, students could watch videos a maximum of two times; the videos locked after two viewings. Additionally, the interface was more user friendly and was

[2]One student in ASL 3 is legally blind. She accesses course lectures and activities through close vision interpreters. She was excluded from the main study because she cannot see clearly enough on a computer screen to participate as sighted students did. Appendix G presents a case study of this student's performance on a modified version of this experiment.

[3]Dr. Jonathan Keane, who has collaborated with me on this and other experiments in this line of work, performed the coding to generate this iteration of the experiment.

Characteristic	*Explicit training*	*Implicit training*
Gender	f = 9, m = 2	f = 7, m = 2, non-binary = 1
ASL 2 grade	A = 6, A- = 2, B+ = 1, B = 1, B - = 1	A = 4, A- = 3, B+ = 3, B = 0, B - = 2
Hearing status	hearing = 9, hh = 2	hearing = 9, hh = 1

Table 5.4: Participant characteristics from Lila's second class by group.

Characteristic	*Explicit training*	*Implicit training*
Gender	f = 37, m = 8	f = 33, m = 9, non-binary = 1
ASL 2 grade	A = 17, A- = 12, B+ = 7, B = 4, B - = 2	A = 16, A- = 14, B+ = 9, B = 4, B - = 3
Hearing status	hearing = 31, hh = 4, deaf = 1	hearing = 42, hh = 1

Table 5.5: Characteristics for all study participants.

supported by more browsers, giving students the opportunity to complete the tests on their own personal computers at their convenience.

Additional features were also superior to those provided by *Qualtrics*. For example, the manual coding of the experimental set-up allowed for full randomization of items. In the previous version of the experiment, items were randomized within each block: practice, allClearA, holds-only, transitions-only, and clear B. So, the word S-O-R-T for example, would only appear in clear A and never in transitions-only, while the word F-A-M-I-L-Y would only appear in holds-only. In this version, the word S-O-R-T could appear in one student's practice block and the word family F-A-M-I-L-Y in the holds-only block, while another participant experienced the opposite. This affords two advantages over the previous *Qualtrics* delivery method. First, it means that all items, including practice items, can be used to fit the statistical model increasing its statistical power. Second, it could be argued that the reason for students' better performance in the holds-only condition could be the result of that block containing more easily understood fingerspelled words. Full randomization means that not all participants experience the same items in the same conditions, which means that if the same results are uncovered (that students perform better in holds-only condition as compared to transitions-only) it is not because of the items they saw, but an actual effect of the experimental condition.

The *Qualtrics* tests from Chapter 4 were password-protected to prevent individuals not associated with the experiment from taking them. The intent with the web-based system is to make it more widely accessible, especially for future studies in which the goal is to collect data from a large number of participants from all over the country. Sharing a password would be tricky and might allow individuals who do not qualify to participate anyway. To combat this issue, pre-experiment four "shibboleth" or Captcha questions verified participants' knowledge of ASL before they could begin. These questions, presented in ASL, were of the format displayed in Figure 5.1. Signs used in the shibboleth test included five cardinal numbers, three lexical items, and two name-signs. Before data collection began, I visited each of the ASL classes to explain the experimental participation requirement. During this time, I reviewed all of the signs they might encounter in the Captcha test.

When students correctly answered all four shibboleth questions, they advanced to the language background survey, and then to the experiment itself. If they missed a question, even due to a typographical error, the following screen informed them that they did not qualify for the study at that time. In this situation, students knew to refresh the page so that new Captcha items would appear and they could try again.

Figure 5.1: Example of a shibboleth test question students had to correctly answer before gaining access to the experiment. Each of the videos, signed in ASL, gave the following instructions, or some near variation of this: `‘‘Below this video frame is a text box. In that text box, please type the equivalent of the ASL sign....’’`A sample video is available here.

After completing the shibboleth test questions, students entered a unique study identification number and advanced to an electronic language background form – though they had also filled-out a paper version in class. Once completed, the experiment began. The next section briefly details what stimuli were used in this project, though it can be noted that they were identical to those used in the pilot project.

5.2.3 Stimuli

Video stimuli for this project consisted of fingerspelling video clips from the corpus collected and annotated by Keane and colleagues (Keane, 2014; Keane et al., 2013c, 2015, 2013a). In their corpus, Keane and colleagues identified stable hand configurations, which they termed *apogees* as periods in which the velocity of the hand was zero or approached zero (Keane, 2014, see §3.2.2 for more detailed information about segment identification in this corpus). In other words, the portion of the signal where the hand is as still as possible is the hold portion. The portions in between held postures are transition segments. Raw video footage was modified in the following ways.

- slowed to half-speed (all: see F-A-C-E and P-A-R-T for two examples of unmasked stimuli)
- black screen masks inserted into the transition portions of each of the clips to create the *holds-only* condition (30 items: see F-A-C-E-holds and P-A-R-T-holds for two examples of holds-only stimuli)
- black screen masks inserted into the hold portions of each of the clips to create the *transitions-only* condition (30 items: see F-A-C-E-trans and P-A-R-T-trans for two examples of transitions-only stimuli)

The same 94 video clips from the previous experiment were used for the pre-test and two post-tests. Four served as practice items for participants to familiarize themselves with the task before it actually began, but recall that in this iteration of the experiment, these four items were randomized across participants. The first full block of 15 tokens had no masking. These served as control items. The second and third full blocks consisted of 30 items each. The final full block of test items consisted of another 15 unmasked items and served as a second control. Words for this list were extracted from the CELEX database filtered for common four- to six-letter words of English (Baayan et al., 1995). The stimulus presentation blocks are presented visually, with examples, in Figure 5.2.

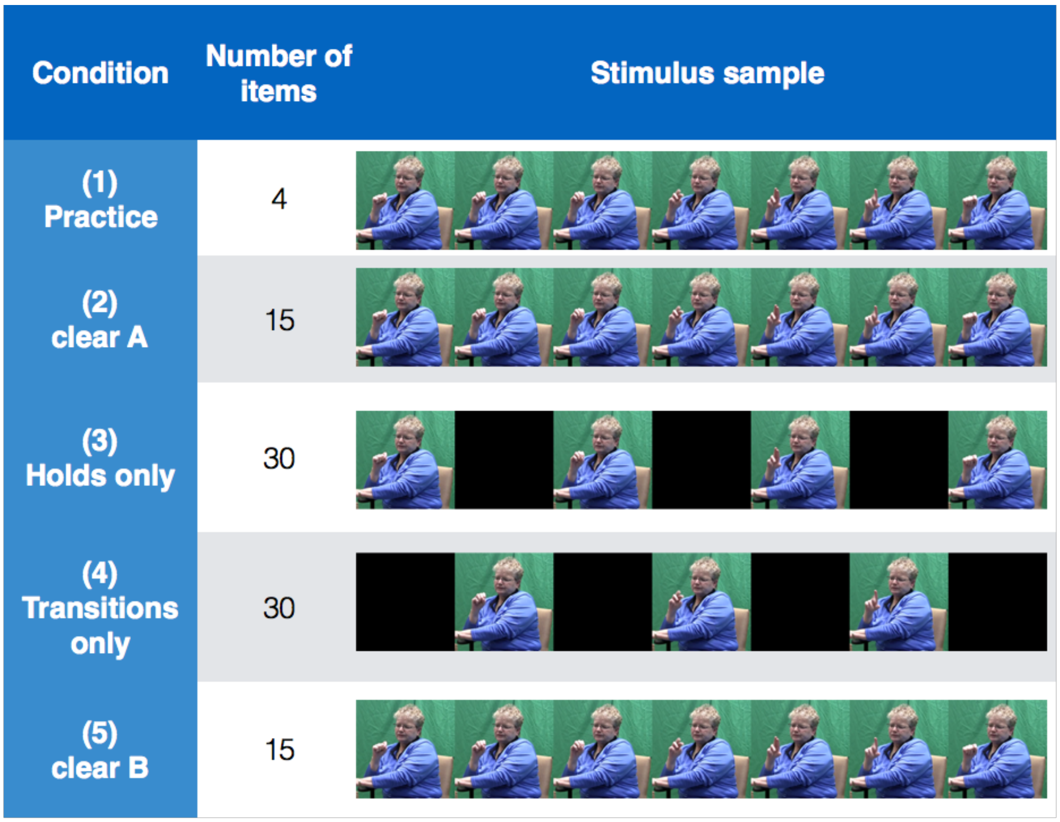


Figure 5.2: Visual representation, with examples, of stimulus block presentations from the experiment in Chapter 4 and in this one.

5.2.4 Timeline

This experiment was conducted during a long fall semester, which lasts fifteen weeks. The ASL curriculum is roughly the same in summer and long semesters. This means it is possible to control for how much ASL knowledge participants had in the experiment. Recall that participants in the pilot completed the pre-test in the first full week of class, the training in the second, and the post-test in the third. So, in order to control for general knowledge of ASL, this timeline was simply stretched out for this iteration of the experiment. Thus, participants completed the pre-test in the third week of class, the training – implicit or explicit – in the sixth week of class, the first post-test in the ninth week of class, and the second post-test in the 12^{th} week of class. As with the first training experiment, reported in Chapter 4, when students had access to pre- or post-tests, they could not access the training, and during the time they could access the training, they could not access the pre- or post-tests.

5.2.5 The training programs

There were no substantive changes to the content of either training program. The delivery method, however, did change in order to make completing it more convenient for students. Changes to the delivery method from Chapter 4 to here are detailed next. To review the training programs in full, please refer to Appendices A and B.

Keynote proved to be a problematic program through which to deliver the mixed-media slide presentation. It can only be run on Apple operating systems and many students have personal computers that operate Windows or Linux. For these students then, the training had to be completed when they were on campus and had access to a lab with Apple computers. Additionally, the version of Keynote in which trainings were built was only compatible with the latest version of the program, which required the most recent operating system (at the time). Students with Apple computers who had not installed that update were forced to using machines available in labs on campus. Even the computers in the ASL classroom of the Department of Linguistics did not have the appropriate operating system initially (I had to ask for them all to be updated rather quickly so participants could complete their assigned training), so their options for where to complete the training portion of this experiment were limited.

To remedy these challenges, the training in this iteration of the experiment was delivered in *Qualtrics*. In order to prevent individuals not associated with the experiment from completing the training, it was password protected. There were several improvements to *Qualtrics* itself from when it was used to deliver the pre- and post-tests in the first experiment. For example, layout features like control of how much content was presented at once, and forward and back buttons, allowed me to very closely replicate the look and feel of the original Keynote presentation, but with greatly improved access.

5.3 Results

As with the previous experiment, the primary goal of this chapter is to assess the efficacy of an intervention training for ASL students. The training program is designed to teach ASL learners explicitly about the structure and phonetic variability in fingerspelling to help them improve their comprehension skills. This has been shown to be an effective teaching technique for students acquiring a spoken L2 (Norris and Ortega, 2000; Ylinen et al., 2010; Giannakopoulou et al., 2013; Saito, 2011, among others) but has never been assessed for hearing ASL learners who are acquiring a second language in a new modality. Given the larger subject pool involved in this experiment, additional research questions could be asked as well. All of the research questions for this experiment are stated below.

1. Is there a difference in student performance between experimental conditions? Based on the results from Geer and Keane (2014) and Keane and Geer (2016),

and those from the experiment reported in Chapter 4, students should perform better in the holds-only condition as compared to the transitions-only condition.

2. Does explicit phonetic training result in greater improvement in student performance on this task? The results from Chapter 4 suggested this was the case, so the same result is expected here as well.

3. Does the effect of the explicit training persist? The first experiment could not test this question as the entire experiment had to be conducted within a very short time frame. Because this experiment was carried out during a long, 15-week semester, there was sufficient time to conduct two post-tests, which allows this question to be addressed. There are two sub-questions which can be asked here. The first is whether students will continue to improve from post-test A to post-test B. The second is whether they will regress, suggesting the results from Chapter 4 were an effect of taking the post-test immediately after the training.

4. Does student performance differ depending on whether items contain letters in which all letters are formed with the default, palm-out orientation versus those that include a letter with non-default orientation as Keane and Geer (2016) found.

Before presenting the results of the statistical analysis, please consider the table of means for the proportion of correct responses by test type, condition, orientation of the palm and training type. Several trends are evident.

- Performance overall is poor.
- Performance on items with default orientation of the palm is better than performance on items with non-default orientation of the palm.

- Performance in the holds-only condition is better than that of performance in the transitions-only condition.

- Participants from the explicit training group performed better on the post-tests than those in the implicit training group.

		Orientation			
		Default		Non-default	
block	testType	implicit mean(SD)	explicit mean(SD)	implicit mean(SD)	explicit mean(SD)
allClearA	pretest	0.418 (0.493)	0.506 (0.500)	0.219 (0.413)	0.286 (0.452)
	posttestA	0.473 (0.499)	0.592 (0.491)	0.290 (0.454)	0.402 (0.490)
	posttestB	0.543 (0.498)	0.665 (0.472)	0.395 (0.489)	0.469 (0.499)
holdsOnly	pretest	0.436 (0.496)	0.463 (0.499)	0.265 (0.441)	0.295 (0.456)
	posttestA	0.501 (0.500)	0.537 (0.499)	0.319 (0.466)	0.355 (0.479)
	posttestB	0.540 (0.498)	0.594 (0.491)	0.377 (0.485)	0.492 (0.500)
transitionsOnly	pretest	0.201 (0.401)	0.198 (0.398)	0.125 (0.331)	0.156 (0.363)
	posttestA	0.259 (0.438)	0.284 (0.451)	0.119 (0.324)	0.230 (0.421)
	posttestB	0.289 (0.453)	0.347 (0.476)	0.212 (0.409)	0.245 (0.430)
allClearB	pretest	0.490 (0.500)	0.512 (0.500)	0.311 (0.463)	0.329 (0.470)
	posttestA	0.469 (0.499)	0.551 (0.497)	0.353 (0.478)	0.436 (0.496)
	posttestB	0.542 (0.498)	0.601 (0.490)	0.428 (0.495)	0.452 (0.498)

Table 5.6: Table of mean proportion of correct responses and standard deviations by test type, condition (block), orientation of the palm, and training for Experiment 2.

To answer the research questions stated above, data from 80 participants were submitted to a mixed effects logistic regression model computed in `R` (RStudio *v. 0.99.48*, R Core Team, 2013) with the package `lme4` (*v1.1-7*, Bates et al., 2015).

Like the previous experiment, responses were matched to the target words with an outcome of *correct* or *incorrect*. Crucially, for this type of model, the outcome variable is binary. This forces predictions into the 0-100% range.

Logistic regression models require that one level of each of the predictors serve as the reference level. This means that the interpretation of Table 5.8, which presents partial output of the statistical model and Appendix E, depends on understanding which level is set as the reference. It may also be helpful to understand why each of these reference levels was selected. Please refer to Table 5.7.

predictor	**number of levels**	**reference level**
test type	3	pre-test
group	2	implicit
condition	4	allClearA
orientation	2	default

Table 5.7: Table of predictor variables and their reference levels

For the test type predictor, the pre-test is the reference level because we are interested in how much change there is from pre-test to post-test A and from pre-test to post-test B. This means that if participants improve from pre- to post-test, we should see a positive number, or a positive number of greater magnitude than in the pre-test. For the group predictor, students who received the implicit training is the reference level because we were interested in learning whether the group which received the explicit training will diverge from the implicit group baseline. The condition predictor has four levels; allClearA is the reference level. This means that all comparisons are related to the first block of the experiment.[4] Positive values represent performance better than the reference level and negative values represent performance worse than on the reference level. We would expect then,

[4]Improved performance on allClearB may reflect practice effects but this is not explored here.

based on Geer and Keane (2014); Keane and Geer (2016), that values would be equal or positive in the holds-only condition and negative in the transitions-only condition. An additional predictor was used in this experiment based on the findings in Keane and Geer (2016), which showed that students perform worse on words that contain letters which have non-default palm orientation. The reference level for this predictor is default which means we would expect to see negative numbers, or worse performance in trials that contain non-default fingerspelled letters.

Additionally, it may be helpful to understand the naming schema used in Table 5.8 and Appendix E. The first part of the name is the variable and the second part is the non-reference level. Interactions are represented with a colon in the name. For example, the variable named `blockholdsOnly` has the variable of "block" and the non-reference level is "holds-only". The name `blockallClearB:testTypeposttestA` represents the interaction between the variables "block" and "test type" with the non-reference levels "allClearB" and "posttestA", respectively.

The dependent variable was binary and evaluated the likelihood of a *correct* response, coded as '1', while *incorrect* responses were coded as '0'. This means it evaluates whether responses match the word that was actually fingerspelled. The predictors input into the `glmer()` function were: `condition` (allclearA, holdsonly, transonly, allclearB), `testtype` (pre-, post-test A, or post-test B), `palm orientation` (default or non-default), and `group` (explicit, implicit) and all of their interactions. The intercept varies based on several grouping variables. These include number in the test, the word they responded to, and subject. The effects of condition and test type were allowed to vary by word and by subject.

Table 5.8 provides the significant results from the statistical model and Figures 5.3 and 5.4 present a visualization of the model predictions. Please see Appendix E for the full output of the statistical model. While Table 5.8 and Appendix E provide the formal results, it may be difficult to interpret given the number of predictors used in this model. I encourage readers to study Figures 5.3 and 5.4, complemented by the text below, to understand what this experiment uncovered. The figures can be read in this way: For any given condition, the dot represents the percentage that were answered correctly in that condition. The line represents the 95% confidence interval.[5] Given the data from this experiment, we expect that 95% of responses will fall into this range. As an example, consider the left-most pane of Figure 5.3: In the first all clear condition (control), individuals assigned to the implicit training group respond correctly on around 37% of the trials with words that have default orientation of the palm.

This analysis does not include any model comparison. Some statisticians argue that the best model is the simplest one, among several, which has similar predictive and explanatory power to those that are more complex (e.g., Aho et al., 2014). The reason to not discard certain predictor variables, even if their coefficient estimates are not significant is because the variable, and any resultant interactions, is theoretically motivated (Gelman and Hill, 2007). In the present experiment, each of the predictor variables is indeed theoretically motivated. Research by Geer and Keane (2014; Keane and Geer, 2016) shows that student performance on fingerspelling tasks is better in holds-only versus transitions-only conditions. The second

[5] NB: Sometimes the length of the confidence interval (CI) lines are an indication of how much variability there is in a particular group/condition. For the conditions in which there was very low overall accuracy, this is not the case. In these cases, the short CI lines are the result of the conversion of the logit space (log odds the model uses) to the probability space (where the results are plotted). As the probability approaches 1 or 0, a bigger change in logit space is required for equal changes in probability space. This is because in logit space the bounds are positive and negative infinity, but in probability space the bounds are asymptotically 1 and 0 (respectively).

of those experiments also reveals a very strong influence of palm orientation on students' comprehension abilities. Previous work on explicit versus implicit instruction in second-language teaching has shown that explicit instruction yields greater gains on post-tests (e.g., Saito, 2007, 2011; Norris and Ortega, 2000, among others) making these two predictors theoretically relevant as well.

To interpret any values that meet significance, again refer to the reference level for that predictor. If an interaction is significant, it means we would expect a stronger (or weaker, depending on the sign of the predictor) response than either variable on its own. When a value is significant, it means that the effect size is big enough to overcome the noise of the variability in the data. The intercept represents the prediction for all reference levels. Here, the value is the prediction for the implicit group in the pre-test in the allClearA condition with items containing only letters with default palm orientation. The value is negative, which indicates that overall performance in this group was poor and that correct answers were provided less than 50% of the time. This value is listed as significant, but that does not bear on any of the research questions.

	coefficient (std error)
(Intercept)	-0.33 (0.28)
blocktransitionsOnly	-1.65 (0.20)***
orientationNon-default	-1.31 (0.39)***
blocktransitionsOnly:orientationNon-default	0.73 (0.35)*
blocktransitionsOnly:orientationNon-default:testTypeposttestA	-0.84 (0.47)$^{\cdot}$
blockholdsOnly:trainingexplicit:testTypeposttestA	-0.67 (0.36)$^{\cdot}$
blocktransitionsOnly:orientationNon-default:trainingexplicit:testTypeposttestA	1.08 (0.64)$^{\cdot}$
blockholdsOnly:orientationNon-default:trainingexplicit:testTypeposttestB	1.11 (0.59)$^{\cdot}$

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

Table 5.8: Mixed effects linear regression coefficient estimates and standard errors.

The first research question asks whether there is a difference in student performance between experimental conditions. Like Geer and Keane (2014); Keane and Geer (2016), this experiment indicates this is indeed the case. There is a significant

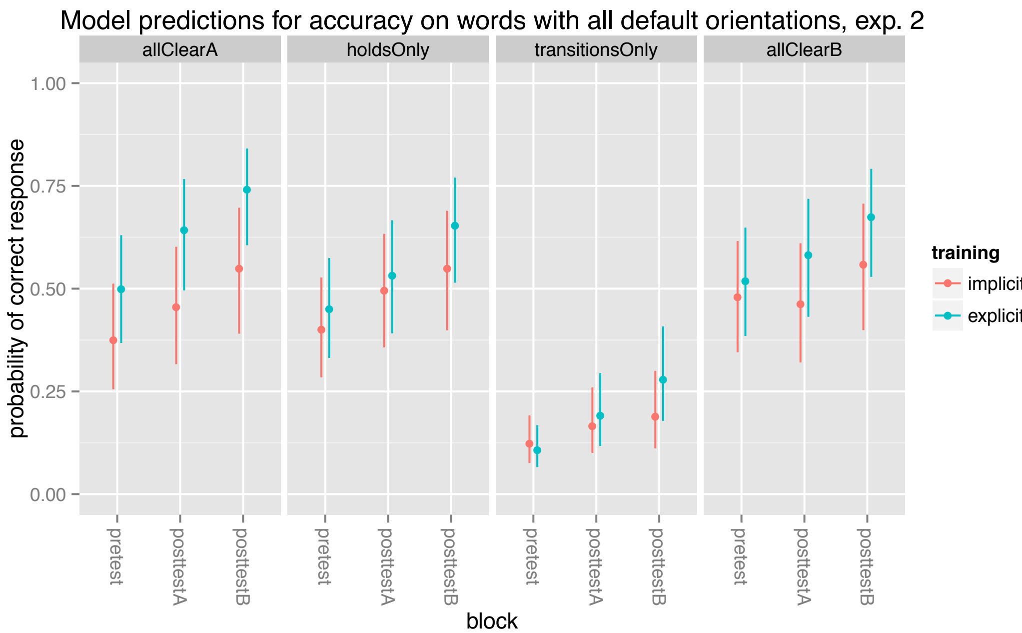


Figure 5.3: Model predictions plot for items containing fingerspelled letters produced with non-default-orientation: Dots represents model predictions, lines represent 95% confidence intervals.

main effect for the transitions-only condition indicating poorer performance on this compared to the allClearA reference level ($p < 0.001$).[6] This difference can also be visualized in Figures 5.3 and 5.4 by comparing the model predictions in the second and third panes.

The second research question asks whether the explicit training impacts student performance on this task? There are two effects which indicate that the training was successful in improving fingerspelling comprehension performance. There

[6] Calculating p-values for this type of model is not a straightforward process (Keane, 2014). There are ways to get around this, however many argue that in lieu of p-values, mixed-effects models are best interpreted with confidence intervals (Bates, 2010; Gelman and Tuerlinckx, 2000; Gelman and Hill, 2007; Gelman, 2013), which are visualized in Figures 5.3 and 5.4.

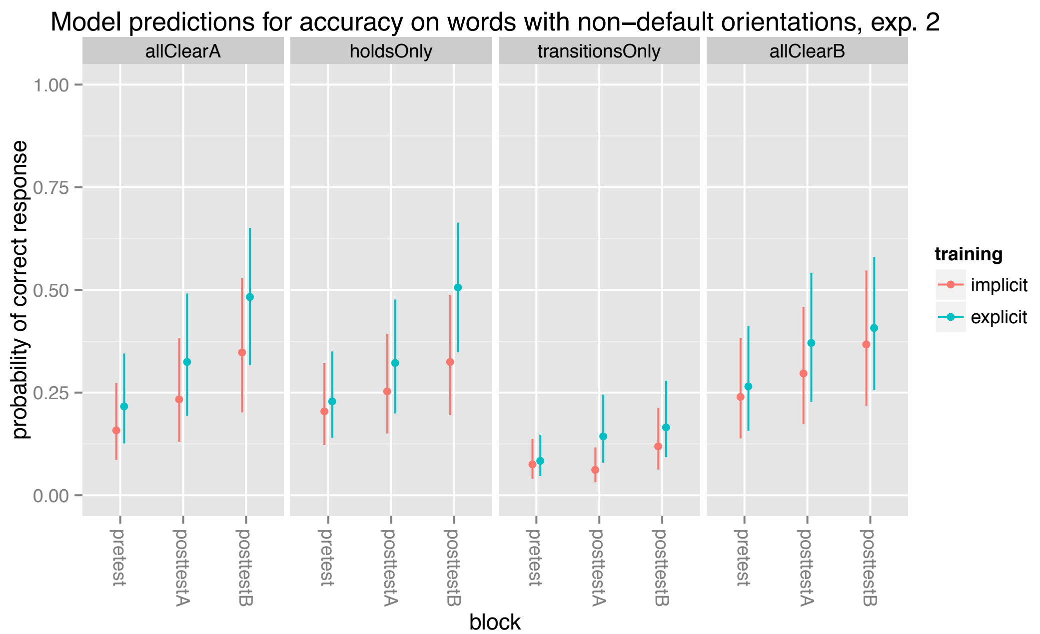


Figure 5.4: Model predictions plot for items with all default-orientation fingerspelled letters: Dots represents model predictions, lines represent 95% confidence intervals.

was a (marginally) significant interaction between the explicit training group, the transitions-only condition and items with non-default orientation on post-tests A and B ($p < 0.1$). Both of these indicate improved performance by participants who received the explicit training on items containing non-default letters in the transitions-only condition.

Question three asks about the persistence of training effects. The study reported in Chapter 4 could not investigate this question because the study was conducted over a very short period of time. One possible interpretation of the results in the previous study is that participants in the explicit training group improved because they had only very recently completed the training program. The present investigation was run over the course of a long, 15-week semester which allows this question to be probed both through a longer gap between training and the first post-test and with a second post-test. While the model does not reveal significant improvement from post-test A to post-test B, it does show a general trend for better performance in the second post-test compared with the first. This trend is visible in the coefficients for most predictors and interactions as well as in the predictions plots in Figures 5.3 and 5.4. This result also indicates that the effects of the training persist at least six weeks after exposure. There is one exception to the lack of significant improvement from the first to second post-test. In the transitions-only condition on items containing non-default palm orientation, students who received the explicit training exhibited further marginally significant improvement from post-test A to post-test B ($p < 0.1$).

The fourth research question asked about the effect of words that contain letters formed with default versus non-default palm orientation. Keane and Geer (2016) found that errors were strongly predicted by the presence of non-default orientation in fingerspelled words, an effect which was not replicated in Chapter 4's study, likely due to insufficient statistical power, given the small number of participants. In the present study, all students, regardless of their training group performed significantly worse on items in which at least one letter was produced with non-default palm orientation ($p < 0.001$).

5.4 Discussion

This experiment uncovered several main findings, three of which replicated previous work. First, ASL students perform better when they are presented with only the hold portion of the fingerspelling signal as compared to transitions-only condition (Geer and Keane, 2014; Keane and Geer, 2016, and Chapter 4). This was true even of students who received the explicit training after they'd completed it; however the training did have a positive effect on students' performance in the transitions-only condition in the post-tests. Second, overall, the intervention training program is successful in helping to improve students' fingerspelling comprehension scores (Chapter 4), though it was more effective in certain conditions as compared with others. Specifically, the explicit training had a stronger effect on performance in the transitions only condition as well as on those items which have non-default palm orientation. Finally, this experiment revealed once again that students struggle more with words formed with letters that are produced with non-default orientation of the palm (Keane and Geer, 2016). In addition to these replicated findings, a new finding was also uncovered. The positive effect of the training program does not appear to be ephemeral; it persisted for at least six weeks after exposure to the 30-40 minute training program. These results are encouraging. Here I discuss these findings further and offer several ways to expand on this work in the future.

Recall from Chapter 3 that the explicit training included two main portions: one which detailed the structure of fingerspelled utterances and one which described features of coarticulation in two fingerspelled letters and two letter combinations. Three of these four lessons on phonetic variation dealt with forms that are produced, at least in part, with non-default palm orientation. Through this training, we might have expected that students would improve more on items with non-default orientation, since this is something the training focused on, as well as improved performance on the transitions only condition, since it is likely that before the training, students were not even aware that useful linguistic information is presented to them during the transition segments. This was not found to be the case, however, in the study presented in Chapter 4. It is possible that one explanation or that lack of a finding is the small number of students who participated in that experiment; there were only a total of 18 students, 9 in each group. The study reported in the present chapter did uncover positive results, even if only marginally significant, suggesting that it is possible to train students to make use of linguistic information in the fingerspelling stream like that which is present in transition segments and particularly that which is introduced as a result of fingerspelled letters which have non-default palm orientation.

This is the second study to show that students struggle more with understanding words which contain letters produced with non-default orientation of the palm and while the training did have some impact on improving comprehension with these tokens students continue to perform the worst in this condition. It would be informative to learn more about the extent of the trouble students have with words of this sort. First, a study would need to be designed which balances the number of tokens with and without non-default orientation. If the training still proves to be ineffective in improving comprehension of these items, it may be useful to investigate the role of position in the word. It may be that there is an effect of location in the word. For example, it could be that -P- word-initially is often confused with -K-, resulting in issues with lexical recall because participants are starting with a list that doesn't contain the correct answer (this could explain the errors like seeing P-L-A-C-E as K-L-A-C-E and P-O-R-T-U-G-A-L as K-O-R-T-U-G-A-L). It could be that word medially or finally, non-default orientation has less of an effect because participants have already generated a list of possibilities that contains the right answer and they're able to use other cues (not those of the non-default letter) to select the correct response (Matthew Dye, personal communication, Oct. 2015).

Future studies should also examine whether an additional aspect of the training designed to target the troublesome transitions-only condition specifically would be helpful. For example, in addition to the intervention program detailed here, students should also complete a training much like the one described in Giannakopoulou et al. (2013). In that study, participants were exposed to highly-variable training with natural and modified stimuli, which was more effective than a natural-only training program. For fingerspelling, this would mean including a portion of the training with modified stimuli which only provide the transition portion of the fingerspelling signal, since that is the portion of the signal which student learners continue to not pay enough attention to. The training should also offer feedback. There are several reasons to believe this type of additional training might be effective. First, we know that exposure to phonetic variation in general is effective in improving foreign language perception (Logan et al., 1992; Pisoni et al., 1994). Second, when provided with impoverished input, perceivers are forced to make use of the information they have in order to complete the task (Holt and Lotto, 2006). This suggests that if this training were designed to address both of these, it would be even more effective in helping students improve their fingerspelling comprehension. Additionally, Giannakopoulou et al. (2013) found less improvement across foreign segment identification tasks for participants trained only on natural stimuli; their participants improved more when trained on natural *and* modified stimuli. This suggests ASL students may benefit from working with the modified stimuli (i.e., transitions-only) such that they are forced to learn to make use of the cues available in that portion of the signal.

A final direction for this work could be to examine ASL learners who are not native speakers of English. There were two non-native English speakers in the

Geer and Keane (2014) study. The statistical model was run twice, once with them and once without. The results did not change but the strength of the effect did, suggesting that their performance was worse than native speakers. It would be instructive to understand whether the same type of phonetic training is useful for non-anglophone learners.

This work also has implications for deaf learners as well. The link between fingerspelling and literacy development in children is clear (Padden, 2006; Humphries and MacDougall, 1999, among others), but how fingerspelling comprehension may impact adult English vocabulary is unclear.

Chapter 6

Conclusions & Future Directions

This dissertation has examined the efficacy of a training program designed to help ASL students improve their ability to understand fingerspelling. In this chapter I first summarize the findings from the studies reported in Chapters 4 and 5. I conclude with a discussion of what types of future studies can be undertaken using the findings from this project.

6.1 Summary of findings from two training studies

Previous work on fingerspelling reveals that it is a challenging skill even for skilled signers, but it appears that deaf signers are able to use information from the whole fingerspelling signal without necessarily attending to each of the individual parts. Hanson (1981) demonstrated this by showing that deaf signers can often correctly identify a fingerspelled word as a real word of English, or a fake word of English, but they cannot always spell it back. Sometimes, signers can even offer appropriate lexical signs as translation equivalents for fingerspelled words, yet still cannot spell them back in English. Schwarz (2000) offers independent evidence for Hanson's conclusion through her study of fingerspelling comprehension using a masking technique. Because deaf participants performed with better accuracy when their responses were evaluated using the Envelope Approach, based on the notion of the *movement envelope* (Akamatsu, 1985), Schwarz concluded that while transition segments alone are not always enough to identify a fingerspelled word exactly, deaf signers are sensitive to cues contained in the transition segments. Results from some of my own work demonstrate that ASL learners do very poorly on comprehension tasks when presented only with transitions in fingerspelling, suggesting they are not able to make use of these cues in the same way skilled signers are (Geer and Keane, 2014; Keane and Geer, 2016).

Previous work on L2 teaching has shown positive results from use of explicit training (Giannakopoulou et al., 2013; Ylinen et al., 2010; Saito, 2011; Dekeyser, 2003; Norris and Ortega, 2000, among others) which allows students to consciously consider (Schmidt, 2001) the ways in which the phonologies of their first and second languages differ. For these studies, all students were learning a second language in the same modality as their first language. This is the first work to examine the use of explicit training with learners who are acquiring a new language also in a new modality. This project involved development and testing of an explicit training program meant to help students improve their ability to understand fingerspelling. The program was developed based on specific challenges my students reported experiencing in fingerspelling comprehension activities as well as on experiments which cues students are sensitive to in a fingerspelling comprehension task (Geer and Keane, 2014; Keane and Geer, 2016). The project also involved development of an implicit training program so that any differences in students' pre- to post-tests was the result of the content of the training program and not the result of more time engaging with a fingerspelling task (cf Thoryk, 2010).

Results from the first training study, reported in Chapter 4, revealed a very strong effect of the explicit training program. Participants performed equally on the pre-test, around 37% accuracy across conditions, and participants in the explicit group performed at around 60% on the post test. They indicated they felt the training program was helpful in helping them to understand fingerspelling as “cursive” rather than “print”, meaning they were able to appreciate the whole of fingerspelled words without paying full attention to the individual parts. But, given the short time-period during which data were collected, it is possible that the positive effect of the explicit training only appeared because participants completed the post-test very soon after the training. The second study afforded the opportunity to test this.

Results from the second training study, reported in Chapter 5 revealed a similar effect as well as several additional findings. Interestingly the main effect of training type was less significant in the second study. However, this study replicated a finding reported in Keane and Geer (2016) wherein students perform significantly worse on items which contain fingerspelled letters produced with non-default orientation of the palm. While students continued to struggle with this category of items after the training, they improved more on these items in the post-test than they did on items with default orientation, suggesting the training was effective in teaching them to make use of cues available in the transition segments of fingerspelling, particularly those related to letters produced with non-default palm orientation.

Additionally, this study included two post-tests in order to probe whether the effects of the explicit training seen in the first study are (a) the result of very recent exposure to the training, and/or (b) ephemeral. The results from the second study suggest that the effects of the training are persistent.

Taken together, these findings suggest that explicit training focusing on phonetic variation in fingerspelling is effective for second language learners who are also acquiring their new language in a new modality. This offers encouraging support for continued investigations of other ways explicit training can be implemented in ASL teaching similar to the ways it has been implemented in the teaching of spoken languages for several decades. There are several ways in which this line of research can be continued in the future. Here I detail several studies which follow naturally from the two presented here.

6.2 Future directions

In their studies of cue re-weighting in Finnish and Greek learners of English, Ylinen et al. (2010) and Giannakopoulou et al. (2013) included personalized feedback in their training programs. When trials were answered correctly, participants were told their answer was right and they advanced to the next trial. On trials for which incorrect responses were provided, participants received feedback indicating this and then were allowed to repeat the trial. The feedback in the training assessed in this thesis was not personalized. Everyone received the same feedback, regardless of how many words they had understood correctly. Future iterations of this project should personalize the feedback in the same way as the studies of Ylinen and colleagues (Ylinen et al., 2010; Giannakopoulou et al., 2013).

In addition to changes in how feedback is delivered, the type of stimuli to which participants are exposed should be varied. Giannakopoulou et al. (2013) demonstrated that training that includes both natural and modified stimuli is more effective than natural-only stimuli. In the case of Giannakopoulou et al.'s study, the modified stimuli were those with equal vowel length, since that was the cue Greek speakers had weighted incorrectly. For a fingerspelling training, this would mean including videos with transitions-only stimuli since that's the condition in which students perform the worst. As I hypothesized in Chapter 4, forcing students to attend to the cues which they don't use currently would likely yield positive results but this needs to be verified experimentally.

Future studies should also examine the effect of palm orientation. In particular, I mentioned in Chapter 4 that Schwarz (2000) found an effect of the position of the masked hold. It may also be the case that the position of the letter with non-default orientation affects student performance. The studies reported here did not use a word-list balanced for palm orientation, and within items with non-default orientation, balanced for position in the word (beginning, middle, or end). This is certainly something to explore in the future not only with ASL students, but with skilled signers as well.

Another study should assess the level at which the training is most beneficial. When I first began discussing fingerspelling in this way with my students and incorporating what has become the explicit training into my teaching, they were in their second semester of language-learning. Students tested in these experiments were in ASL 3. The ideal time to begin this type of exposure to and discussion of the structure of fingerspelling and explicit phonetic variation therein remains an empirical question. Presumably at some point the training will become less effective or possibly ineffective because second-language learners will already have learned/deduced through experience with the language what weights to assign to various cues in the fingerspelling stream. A study of this using the same procedures as in Geer and

Keane (2014), Keane and Geer (2016) and in this dissertation is underway. Data from skilled L2 signers will speak to whether they've learned to use these cues in a fashion similar to deaf signers who acquire ASL from birth.

A slightly related, but still different empirical question, is how this type of training might impact signers who are skilled at a two-handed alphabet like British Sign Language (BSL) and acquire ASL in adulthood. There may be aspects of their acquisition process that are facilitated because of prior knowledge of a language in the visual-gestural modality, but there might also be aspects that remain difficult and indicate that some type of phonetic training may be helpful. For instance, BSL signers will have experience both with the simultaneous structure of signs and the sequential structure of fingerspelling. However, ASL fingerspelling uses more handshape distinctions than BSL fingerspelling, which uses mostly unmarked handshapes. This difference may cause problems for BSL signers attempting to acquire ASL fingerspelling comprehension skills.

The studies reported in this dissertation and those mentioned above which follow naturally from this dissertation involve predominantly native speakers of English. Geer and Keane (2014) did include two non-native speakers of English. Two models were run: one which included all participants and one which included only native English speakers. The results were the same but the effect was slightly weaker when non-native English speakers were included. This raised the possibility that for hearing learners English proficiency may impact fingerspelling comprehension. It is not clear, however that English proficiency in deaf signers is similarly detrimental to their fingerspelling performance. It might be interesting, therefore, to match native signers with skilled ASL L2 users whose first language is not English, on English proficiency and vocabulary, and examine any differences in fingerspelling comprehension ability.

In addition to the studies noted above, there are several ways in which the training itself should be improved in the future. Instruction on additional types of phonetic variation which have been discussed in the literature would very likely be beneficial, particularly on those types of variation which students have noted are particularly problematic for them. These additional topics should include: (1) the production of -P- and the amount of flexion of the wrist/rotation of the forearm (refer back to Figure 2.6 in Chapter 2), (2) pinky extension (see Keane, 2014; Thumann, 2009) and (3) -X- and -D-, for which variation is actually discussed to some minimal extent in the textbook (Smith et al., 2008) but students do not seem able to use this information.

All of these suggested future studies explore explicit training practices and how they may be useful in M2 training. Much of ASL pedagogy has historically been based on teacher intuition, rather than empirically-grounded methods. The work detailed here demonstrates the positive gains possible when research informs language teaching and when language teaching informs research projects.

Appendix A

Explicit Training

Slide 1

Fingerspelling training

A

Slide 2

How to use this training

- Go through these slides at a pace that's comfortable for you.
- You may, at any time, go back and forth, but do make sure you see all the slides.
- Some videos are included in the presentation. Feel free to watch them as many times as you like.
- Think about the content of the training with respect to both fingerspelling production and comprehension.

- After the training, you'll take the same test you took recently and the goal is to improve, so do think carefully about the topics that are covered.

Slide 3

Fingerspelling

- In this presentation, you'll learn about the structure of fingerspelling.
- As you go through, think carefully about what these lessons mean for both fingerspelling production and comprehension.
- Throughout this training, you'll have the opportunity to practice your comprehension skills, so pay close attention.

Slide 4

Structure

- Fingerspelling can be divided into periods of holds and periods of transitions.
- Let's look at what these mean.

Slide 5

Clear - labeled

- Here is a series of still images of the fingerspelled word SORT.
- Do you notice anything different about the odd- versus even-numbered frames?

-S-	S-O	-O-	O-R	-R-	R-T	-T-
1	2	3	4	5	6	7

Slide 6

Clear

- The odd-numbered frames are holds and the even numbered frames are transitions.

-S-	S-O	-O-	O-R	-R-	R-T	-T-
1	2	3	4	5	6	7

Let's look at what this means more closely.

Slide 7

Holds

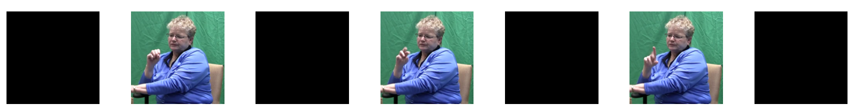
- Holds are periods where the signer holds a handshape without moving for a brief period of time.
- Notice that in each of the visible frames below, you can't see any blurring in the image, which would indicate movement.

-S- S-O -O- O-R -R- R-T -T-

Slide 8

Transitions

- Transitions are periods during which signers transition from letter posture to letter posture.
- Notice that each visible frame below is slightly blurry. This indicates movement.



-S- S-O -O- O-R -R- R-T -T-

Slide 9

Transitions

- Notice that in these transitions you can see features of the letter before and after the upcoming letter.

S-O

Not as closed as a full -S-.

O-R

Opening from -O-, but index and ring finger not yet fully extended.

R-T

Middle and index fingers spread to make room for thumb insertion for -T-.

Slide 10

See if you can tell which parts are holds and which are transitions

[video of the fingerspelled word S-O-R-T]

Slide 11

That was the word S-O-R-T.

Watch again.

[video of the fingerspelled word S-O-R-T]

Slide 12

Other examples

- Let's look at some other ways in which manual letters may be produced differently in the context of other letters.

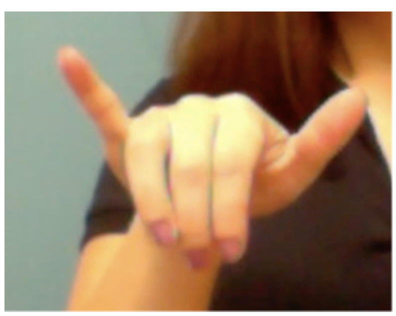
Slide 13

-Y-

- The letter -Y-, when produced in isolation, has normal orientation and bending at the wrist.
- But, often times, when it's in the middle or end of a word, signers will add a bend at the wrist to help this letter stand out.
- Let's look at some examples.

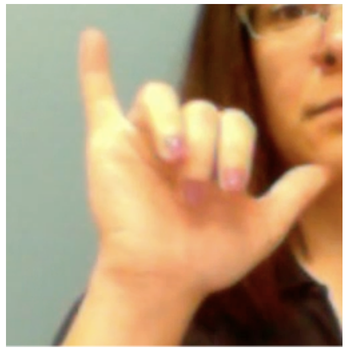
Slide 14

-Y-



word final: BOY

word internal: HIMALAYA



word final: YOSEMITE

Slide 15

-Y-

[video of words with -Y- in various positions: BOY, OYSTER, OLYMPICS, HIMALAYA, YARD and YOSEMITE.]

Slide 16

-Y-

These were the words BOY, OYSTER, OLYMPICS, HIMALAYA, YARD and YOSEMITE. Did you understand them all? Watch again.

Slide 17

-Y-

[video of words with -Y- in various positions: BOY, OYSTER, OLYMPICS, HIMALAYA, YARD and YOSEMITE.]

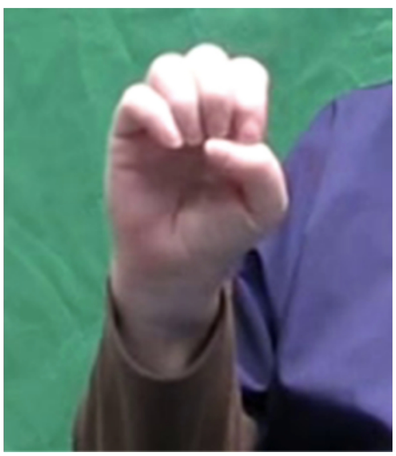
Slide 18

-E-

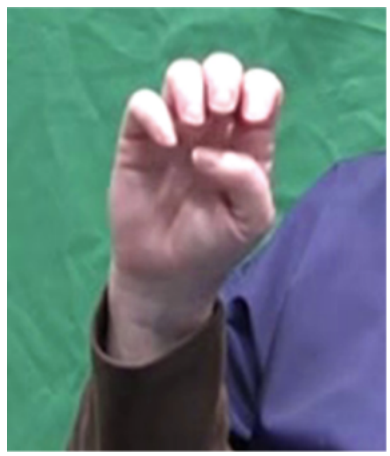
- -E- is highly susceptible to slight changes based on the surrounding letters.
- Let's look at some of the various ways this letter may be produced.

Slide 19

Closed and Open -E-



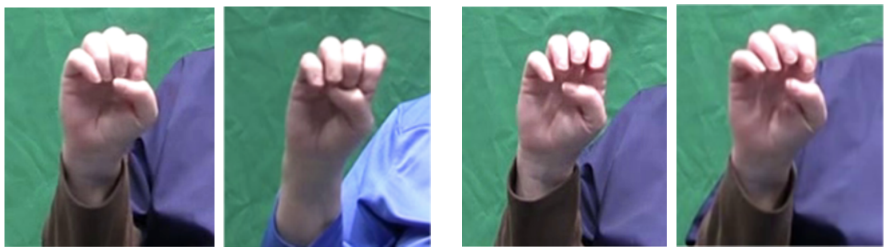
This production of -E- is known as closed because the index, middle, and maybe also ring finger make contact with the thumb.



This production of -E- is known as open because the none of the fingers make contact with the thumb.

Slide 20

-E-



Closed -E-　　　　Open -E-

When might one or the other form be preferred?

This depends on a host of factors including position in the word, the preceding and following letter, rate of fingerspelling, personal signing style.

Slide 21

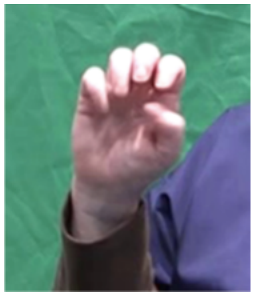
Other -E- variants

- -E- may also vary with respect to how many fingers make contact with the thumb, if any at all.
- Let's look at two examples from the same word.

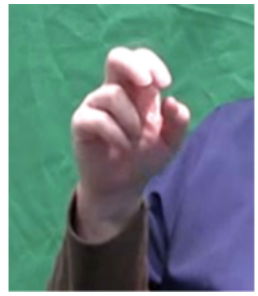
Slide 22

Other -E- variants

excerpted from the word T-E-A-C-H-E-R



-E- is open because it follows the completely closed letter -T-



-E- is open and only the index and middle fingers are involved because the preceding letter is -H- and the following -R- which primarily involve the index and middle fingers

Slide 23

See if you can catch different formations of the letter -E-

[video of the fingerspelled word T-E-A-C-H-E-R]

Slide 24

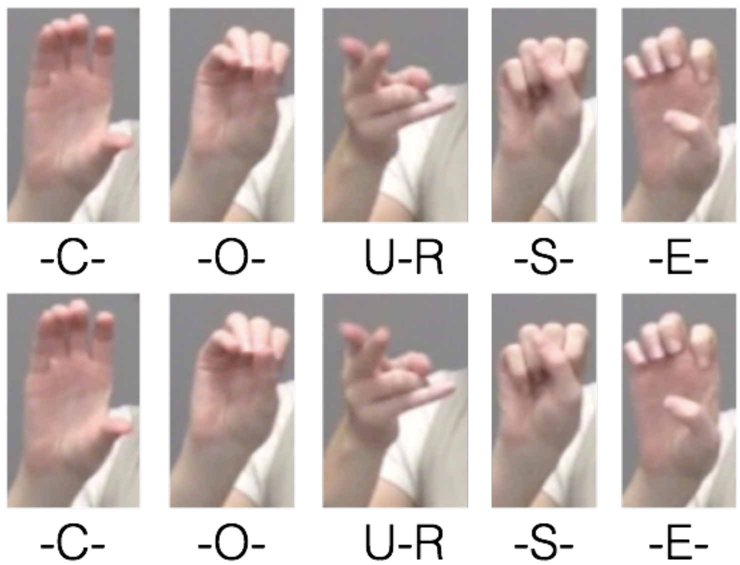
U-R combos

- Let's look at another example of how transitions can be important in understanding fingerspelling.
- Often, when the letters U-R appear in sequence, signers add an additional movement.

- This means neither letter might look as it would if it were produced alone, but the additional movement indicates the appearance of these letters as a pair.

Slide 25

U-R combos



The U-R combination is produced with an additional wrist and forearm movement. The handshape looks like something in between a -U- and an -R-.

Slide 26

Words with U-R combos

[video with the words SOURCE, COURSE and TAMBOURINE]

Slide 27

Check your comprehension

These were the words SOURCE, COURSE and TAMBOURINE. Did you understand them all? Watch again.

Slide 28

[video with the words SOURCE, COURSE and TAMBOURINE]

Slide 29

G-H-T

- A number of English words end with the letter combination G-H-T.
- These letters often blend together as a single unit.
- Upon seeing this at the end of a word, good guesses would include words like 'night', 'ought', 'fight', etc.

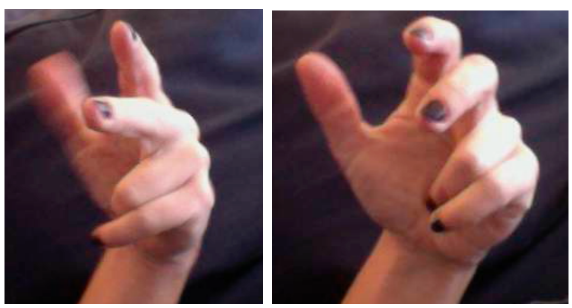
Slide 30

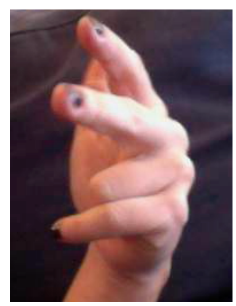
G-H-T

- What do you notice about these images?
- Think about what you've just learned about holds and transitions. Also think about how the letters are formed in isolation and how that is similar or different to what you see here.

Slide 31

G-H-T





In these two images the pinky is still partially extended from the preceding letter -I-. The palm is partially rotated inward for production of the letters -G- and -H- but the index and middle fingers are spread in anticipation of the upcoming -T-.

At this point the pinky is mostly flexed and the palm has returned almost completely to the outward orientation required for -T-.

Slide 32

See if you can catch this letter combination chunk

[video with the words NIGHT, MIGHT, OUGHT, FIGHT and FLIGHT]

Slide 33

Check your comprehension

These were the words NIGHT, MIGHT, OUGHT, FIGHT and FLIGHT. Did you understand them all? Watch again.

Slide 34

[video with the words NIGHT, MIGHT, OUGHT, FIGHT and FLIGHT]

Slide 35

More practice: How many words can you catch?

[video with the words NIGHT, EARTH, REPORT, STAGE and BODY]

Slide 36

Answers

- Check your comprehension. How many words did you correctly identify?
- Here are the answers. NOTE: Each item is spelled twice.

1. NIGHT 2. EARTH 3. REPORT

4. STAGE 5. BODY

Slide 37

Summary

- Fingerspelled words can be divided into holds and transitions.
- Holds are periods where the letter posture is held statically. There is no movement in still images.
- Transitions are periods in which signers transition from one letter posture to the next. Features of the preceding and following letterÕs handshape are present. Still images may be partly blurry, indicating movement.

Slide 38

Summary

- Sometimes letters are produced differently in fingerspelled utterances than they might be on their own.
- This functions to
  - make letters more distinct and/or
  - make production of certain letter combinations easier
- Sometimes frequently produced letter combinations take on a shape of their own.

Slide 39

What now?

- In several weeks you'll take another fingerspelling test, very much like the one you took recently.
- Use what you've learned in this training to try to improve your score from last time.
- Good luck!

Appendix B

Implicit Training

Slide 1

Fingerspelling training

B

Slide 2

How to use this training

- Go through these slides at a pace that's comfortable for you.
- You may, at any time, go back and forth, but do make sure you see all the slides.
- Some videos are included in the presentation. Feel free to watch them as many times as you like.
- Think about the content of the training with respect to both fingerspelling production and comprehension.

- After the training, you'll take the same test you took recently and the goal is to improve, so do think carefully about the topics that are covered.

Slide 3

Fingerspelling

- In this presentation, you'll learn about different aspects of fingerspelling.
- As you go through, think carefully about what these lessons mean for both fingerspelling production and comprehension.
- Throughout this training, you'll have the opportunity to practice your comprehension skills, so pay close attention.

Slide 4

The manual alphabet

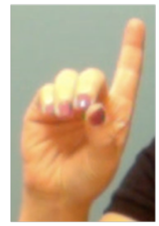
- As you've learned in class, ASL has manual representations for each of the letters in the English alphabet.
- Fingerspelling is a process in which you produce these manual letters in sequence to form a word.
- Let's look at the correct way to produce each of these now.
- As you go through each of these slides, practice forming each of the letters.

Slide 5

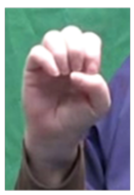
A

B

C

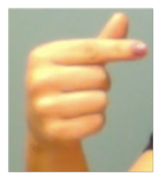


D

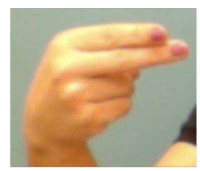


E

F

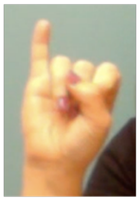


G

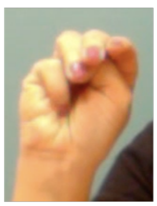
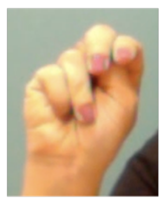
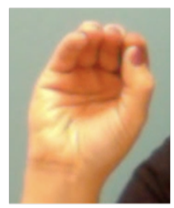
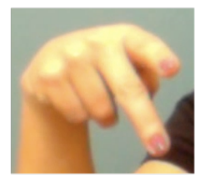


H

Slide 6




I J K L

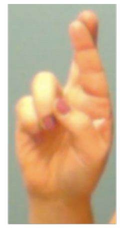





M N O P

[the letter -J- is a video since this letter involves movement]

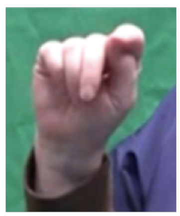
Slide 7

Q

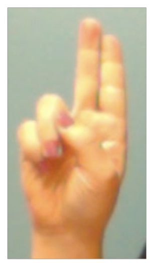


R

S



T



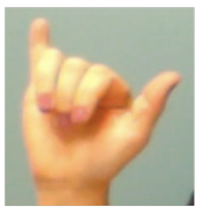
U

V

Slide 8

W

X



Y

Z

[the letter -Z- is a video since this letter involves movement]

Slide 9

Let's look at an example

[video of the word S-O-R-T]

Slide 10

That was the word S-O-R-T.

Watch again.

[video of the word S-O-R-T]

Slide 11

Still images

- Here is a series of still images of the word you just saw.

-S- S-O -O- O-R -R- R-T -T-

Slide 12

Now let's look at a few letters more closely

- Notice that most of the letters have an outward palm orientation. That is, you as the signer canÕt see your palm, whereas someone looking at you fingerspelling could.

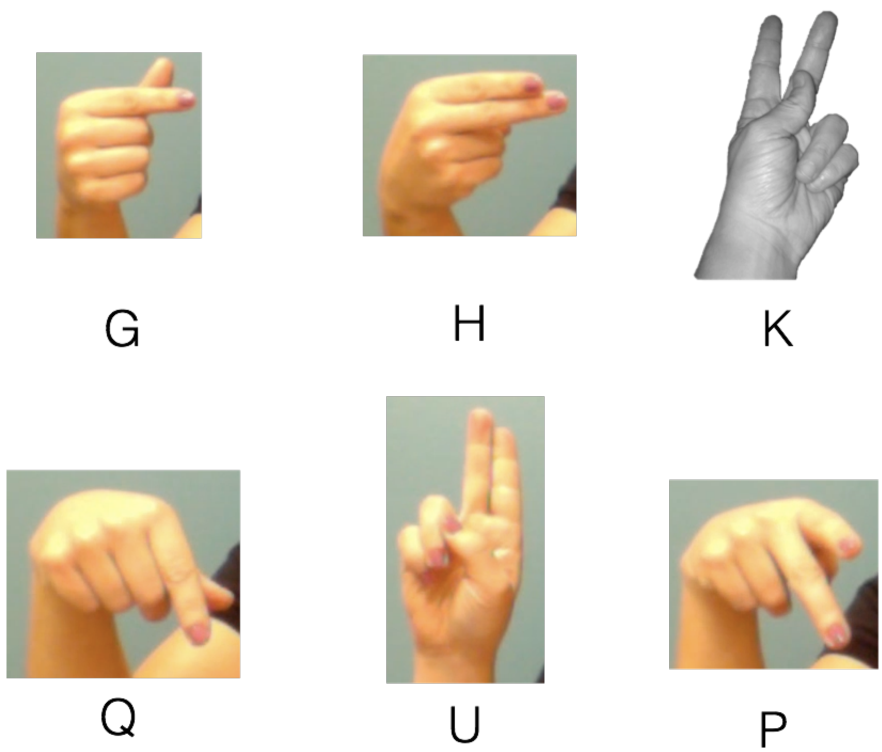
- But there are a few exceptions to this generalization.

Slide 13

G & Q/ H & U/ K & P

- Unlike most manual letters, which are distinguished by distinct hand configurations, these three letter pairs are distinguished by changes in orientation, or where the palm faces.

Slide 14



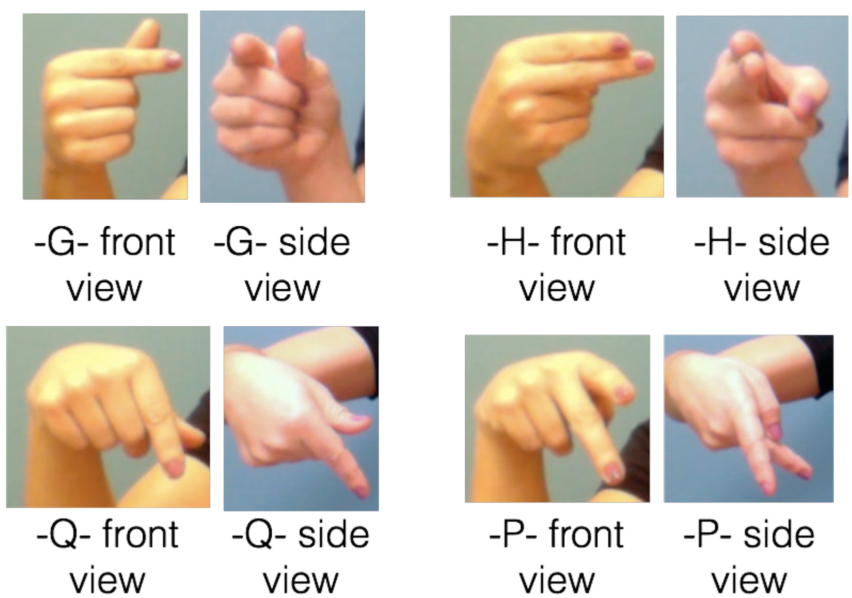
Slide 15

Palm-in letters

- Unlike most letters, the pair G & H face inward.
- In addition to facing inward, the pair P & Q also involve a bending at the wrist; they face in and down.
- Here are these letters again with a side view.

Slide 16

Palm-in letters: Front & side views



Slide 17

Let's look at another example

[video of the word T-E-A-C-H-E-R]

Slide 18

That was the word T-E-A-C-H-E-R Watch again.

[video of the word T-E-A-C-H-E-R]

Slide 19

More practice!

- Now you've reviewed the whole alphabet, seen how some letters differ in their handshape, while other differ in their palm orientation, and you've seen some examples in isolation.
- Now let's look at a few more examples.

Slide 20

How many words can you catch?

[video with the words NIGHT, EARTH, REPORT, STAGE and BODY]

Slide 21

Answers

- Check your comprehension. How many words did you correctly identify?
- Here are the answers. NOTE: Each item is spelled twice.

1. NIGHT 2. EARTH 3. REPORT

4. STAGE 5. BODY

Slide 22

Watch again.

[video with the words NIGHT, EARTH, REPORT, STAGE and BODY]

Slide 23

Here are some other words

[video of the fingerspelled word BOY, OYSTER, OLYMPICS, HIMALAYA and YOSEMITE]

Slide 24

Check your comprehension

These were the words BOY, OYSTER, OLYMPICS, HIMALAYA and YOSEMITE. Did you understand them all. Watch again.

Slide 25

[video of the fingerspelled word BOY, OYSTER, OLYMPICS, HIMALAYA and YOSEMITE]

Slide 26

Double letters

- There are different ways to produce words with double letters.
- Sometimes it depends on the letter that's doubled, other times it's a matter of personal preference.
- Let's look at these options

Slide 27

Double letters: Sliding

[videos of the fingerspelled words ABERDEEN, BEEN and BOOM]

Slide 28

Double letters: Tapping

[videos of the fingerspelled words JIMMY and BEER]

Slide 29

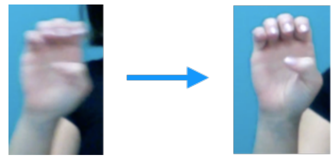
Double letters: Bouncing

[videos of the fingerspelled words BALL and OFFICE]

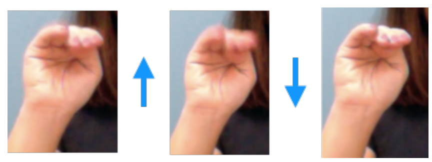
Slide 30

Double letters: Summary

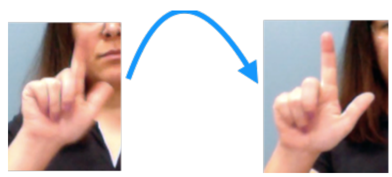
- Sliding – the doubled letter moves slightly away from the signerÕs body



- Tapping – Active fingers are tapped on the non-active fingers. This technique is more prevalent with letters like -N-, -M-, -T-, and -S-



- Bouncing – the doubled letter bounces away from the signer's body



Slide 31

And a few more. . .

[video of the fingerspelled words SOURCE, COURSE and TAMBOURINE]

Slide 32

Check your comprehension

[video of the fingerspelled words SOURCE, COURSE and TAMBOURINE]

- These were the words SOURCE, COURSE and TAMBOURINE. Did you understand them all? Watch again?

Slide 33

[video of the fingerspelled words SOURCE, COURSE and TAMBOURINE]

Slide 34

And a few more still...

[video of the fingerspelled words NIGHT, MIGHT, OUGHT, FIGHT and FLIGHT]

Slide 35

Check your comprehension

- These were the words NIGHT, MIGHT, OUGHT, FIGHT and FLIGHT. Did you understand them all? Watch again.

Slide 36

[video of the fingerspelled words NIGHT, MIGHT, OUGHT, FIGHT and FLIGHT]

Slide 37

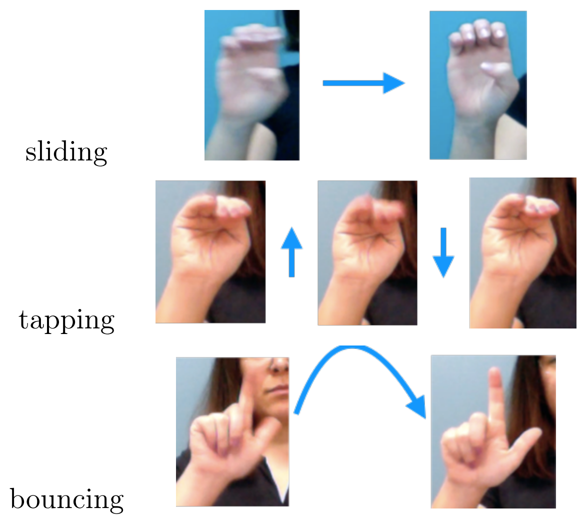
Summary

- Fingerspelling is a process in which you produce these manual letters in sequence to form a word.
- Fingerspelling should be produced smoothly and clearly.

Slide 38

Summary

- There are several ways to produce double letters. These include



Slide 39

What now?

- In several weeks you'll take another fingerspelling test, very much like the one you took recently.
- Use what you've learned in this training to try to improve your score from last time.
- Good luck!

Appendix C

J&L notation description & examples

C.1 Introduction

Stokoe et al. (1965) provided the first systematic documentation of the sublexical structure of signs in The *Dictionary of American Sign Language*, or the DASL. Authors identified three aspects of sign production to be documented: handshape (19 values), place of articulation (12 values), and movement (24 values). Battison (1978) suggested orientation of the palm as an formational additional parameter of signs.

While Stokoe Notation is fairly easy to learn and use, much information about sign formation cannot be unambiguously captured with this system because of the limited set of values it offers. For example the symbol -G- is used to describe any handshape in which the index finger is extended, including the manual letter -D- and the number -1-, yet each of these is a distinct handshape; see Figure C.1. Because the focus here is on phonetic rather than categorical distinctions in fingerspelling, a system which can capture more minute differences is required. Here I describe the mechanics of the phonetic notation system for hand configuration and palm orientation developed by Robert Johnson and Scott Liddell (Johnson and Liddell, 2011, 2012, henceforth *J&L*). Recall that the term *handshape* refers to the mental representation the form the hand takes, or the phonological form, while *hand configuration* refers to the phonetic realization of a particular handshape which may or may not look like the citation form (Johnson and Liddell, 2011; Whitworth, 2011; Keane, 2014).

Figure C.1: Images of different handshapes, all of which would be represented with the symbol -G- in Stokoe notation, but are in fact distinct handshapes.

C.2 Hand configuration

Hand configuration in the *J&L* system accounts for the behavior of each of the joints in the fingers and thumb, indicated in Figure C.2. It also provides a means by which to characterize the relationship of the fingers to one another (i.e., spread/not spread apart, crossed) and relationship of fingers to the thumb (i.e., opposition of the latter). There are four basic types of annotations in hand configuration: the attitude of the fingers, the amount of spread of the fingers, opposition of the thumb and contact. Each is described briefly below with examples.

Figure C.2: Joints of the hand that require notation in the *J&L* system.

C.2.1 The attitude of the fingers

The attitude of the fingers is indicated by one of six values in three categories: flexion, extension, and hyperextension. See Table C.1.

Flexion	**Extension**	**Hyperextension**
F = fully flexed	E = fully extended	H = fully hyperextended
f = partially flexed	e = partially extended	h = partially hyperextended

Table C.1: *J&L* values for finger extension.

C.2.2 Spread in the fingers

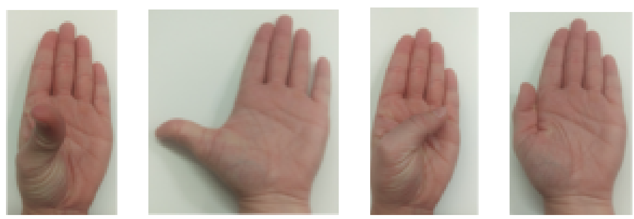
The amount of spread in the fingers – abduction refers to spreading and adduction refers to bringing the fingers in closely to one another – is indicated by one of three values presented in Table C.2.

Position	**Symbol**
Fully adducted	$=$
Partially abducted	$<$
Fully abducted	$\langle$

Table C.2: *J&L* values for finger abduction and adduction.

C.2.3 The thumb

The thumb uses the same notation systems for flexion/extension of the joints and ab/adduction, but also requires an additional feature: that of opposition. The thumb is opposed when it crosses to meet another digit. It may or may not make contact. Figure C.4 presents the four basic combinations the thumb can have with respect to ab/adduction and opposition.



(a) (b) (c) (d)

Figure C.3: Picture examples of positions of the thumb. (a) is opposed and fully abducted, (b) is unopposed and fully abducted, (c) is opposed and fully adducted, and (d) is unopposed and fully adducted.

C.2.4 Contact

When the thumb makes contact with another digit or digits, several aspects of that contact have to be indicated. The part of the thumb that contacts the other finger has to be indicated. There are three possible values: the ventral or palm side, which is known as 'friction contact', the tip, or the back surface. Where the thumb contacts the other digit(s) must also be indicated by stating the bone it contacts (which phalange, proximal, medial, or distal), and on which surface, radial (thumb side), tip, or ulnar (pinky side).

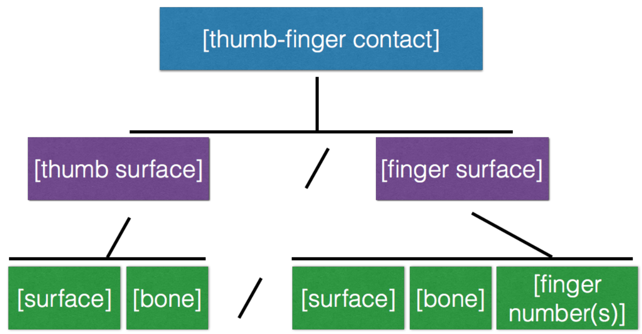


Figure C.4: Graphic describing how to indicate where and how the thumb makes contact with other digit(s).

C.2.5 Examples

To implement each of these pieces of the hand configuration notation system, consider again the two tokens discussed in Chapter 3 repeated here as Figure C.5. Table C.3 indicates what symbols are used for each of the aspects of the hand configuration notation.

(a) (b)

Figure C.5: Two example ASL handshapes: (a) -L- handshape and (b), "double-z" handshape.

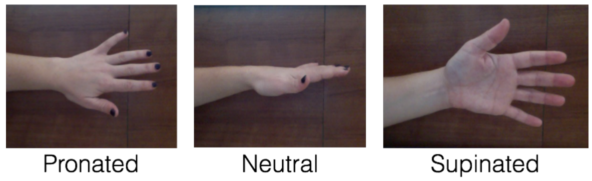
NOTATION SCHEMA	Figure C.5a	Figure C.5b
1. thumb opp	O	U
2. thumb MCP & PIP ext	fF	Eh
3. arr btwn T & fingers	=	⟨
4. *how thumb contacts finger*	fd/bm3	
5. index MCP, PIP & DIP ext	1hff	EEE
6. arr between 1 & 2	<	<
7. middle MCP, PIP & DIP ext	2hff	fFf
8. arr between 2 & 3	<	=
9. ring MCP, PIP & DIP ext	3FFe	FFf
10. arr between 3 & 4	=	=
11. pinky MCP, PIP & DIP ext	4FFe	FFf

Table C.3: Table presenting implementation of the *J&L* hand configuration notation system. The left column describes schematically what can be represented by the system and the middle and right columns provide an example of this notation using the -L- and 'double-Z' handshapes as examples.

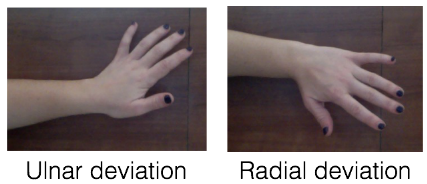
C.3 Orientation

Unlike Stokoe et al. (1965) who consider orientation of the palm to be part of the handshape specification, *J&L* consider it separately. Very generally, the notation of orientation involves indicating how much flexion or extension there is at a particular joint. If there is another axis around which a joint rotates, that can be indicated as well. There is a means by which to annotate the wrist, forearm, elbow, and shoulder, though the elbow and shoulder are less frequently relevant in fingerspelling data. For fingerspelling, the most relevant aspects of the *J&L* system are pictured in Figure C.6. These can be further modified with the symbol '∪', which indicates halfway between two values.

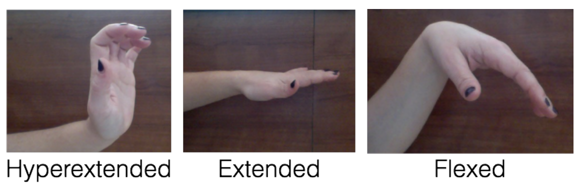
Here are some examples of how to implement notation of hand configuration and orientation.



(a) Facing of the palm

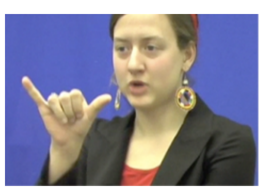


(b) Deviation of the wrist

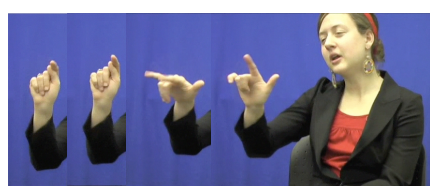


(c) Flexion of the wrist

Figure C.6: Values for orientation representation in *J&L*



(a)



(b)

Figure C.7: Citation form production of -Y- by a native signer (a), followed by use of this letter in context in the abbreviation T-T-Y-L (b).

Citation Form

Letter	HandConfig	PalmOr
-Y-	LEH⟨1FFe<2FFe=3FFe<4EEE	ElFlx,WrExtNeut

Context

Letter	HandConfig	PalmOr
-T-	fd/um1 Oee=1fff=2FFE=3FFE=4FFE	ShFlx∪, ElFlx, prone∪, WrExtNeut
-T-	fd/um1 Oee=1ffe=2FFE=3FFE=4FFE	
-Y-	LEH<1eee=2fFe=3fFe<4EEE	ElFlx∪, WrFlx∪
-L-	LEH$\underline{<\text{1eEE}}$<2fFf=3fFf=4EFf	ElExt∪, WrExtNeut

Table C.4: *J&L* notation for Figure 3.4

Appendix D

Mixed effects logistic regression model output: Experiment 1

predictor	**number of levels**	**reference level**
test-type	2	pre-test
group	2	group B (implicit training)
condition	4	clear A

Table D.1: Table of predictor variables and their reference levels

	coefficient (standard error)
(Intercept)	-1.26 $(0.53)^{*}$
conditionclearB	1.42 (0.76)
conditionholdsOnly	0.68 (0.56)
conditiontransOnly	-0.91 (0.56)
testTypePostTest	-0.26 (0.51)
groupA	0.68 (0.50)
conditionclearB:testTypePostTest	-0.24 (0.56)
conditionholdsOnly:testTypePostTest	0.44 (0.47)
conditiontransOnly:testTypePostTest	0.18 (0.50)
conditionclearB:groupA	-0.62 (0.57)
conditionholdsOnly:groupA	-0.59 (0.43)
conditiontransOnly:groupA	-0.38 (0.47)
testTypePostTest:groupA	1.68 $(0.68)^{*}$
conditionclearB:testTypePostTest:groupA	-0.58 (0.75)
conditionholdsOnly:testTypePostTest:groupA	-0.98 (0.62)
conditiontransOnly:testTypePostTest:groupA	-1.18 (0.65)
AIC	2636.29
BIC	2912.04
Log Likelihood	-1271.14
Num. obs.	2610
Num. groups: qNumber	90
Num. groups: word	90
Num. groups: group:subjCode	16
Variance: qNumber.(Intercept)	0.00
Variance: word.(Intercept)	2.01
Variance: word.conditionclearB	0.30
Variance: word.conditionholdsOnly	0.01
Variance: word.conditiontransOnly	0.10
Variance: word.testTypePostTest	0.05
Variance: group:subjCode.(Intercept)	0.52
Variance: group:subjCode.conditionclearB	0.31
Variance: group:subjCode.conditionholdsOnly	0.06
Variance: group:subjCode.conditiontransOnly	0.08
Variance: group:subjCode.testTypePostTest	0.66
Variance: Residual	1.00

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table D.2: Mixed effects logistic regression coefficient estimates and standard errors.

Appendix E

Mixed effects logistic regression model output: Experiment 2

predictor	number of levels	reference level
test type	3	pre-test
group	2	implicit
condition	4	allClearA
orientation	2	default

Table E.1: Table of predictor variables and their reference levels

	coefficient (std error)
(Intercept)	-0.33 (0.28)
blockholdsOnly	-0.16 (0.19)
blocktransitionsOnly	-1.65 (0.20)***
blockallClearB	0.13 (0.22)
orientationNon-default	-1.31 (0.39)***
trainingexplicit	0.17 (0.26)
testTypeposttestA	0.04 (0.32)
testTypeposttestB	0.48 (0.35)
blockholdsOnly:orientationNon-default	0.41 (0.32)
blocktransitionsOnly:orientationNon-default	0.73 (0.35)*
blockallClearB:orientationNon-default	0.22 (0.36)
blockholdsOnly:trainingexplicit	0.10 (0.26)
blocktransitionsOnly:trainingexplicit	-0.20 (0.28)
blockallClearB:trainingexplicit	0.04 (0.30)
orientationNon-default:trainingexplicit	0.29 (0.35)
blockholdsOnly:testTypeposttestA	0.38 (0.26)
blocktransitionsOnly:testTypeposttestA	0.32 (0.27)
blockallClearB:testTypeposttestA	-0.17 (0.29)
blockholdsOnly:testTypeposttestB	0.17 (0.26)
blocktransitionsOnly:testTypeposttestB	0.08 (0.28)
blockallClearB:testTypeposttestB	-0.03 (0.31)
orientationNon-default:testTypeposttestA	0.31 (0.36)
orientationNon-default:testTypeposttestB	0.47 (0.36)
trainingexplicit:testTypeposttestA	0.62 (0.43)
trainingexplicit:testTypeposttestB	0.66 (0.45)
blockholdsOnly:orientationNon-default:trainingexplicit	-0.41 (0.43)
blocktransitionsOnly:orientationNon-default:trainingexplicit	-0.13 (0.47)
blockallClearB:orientationNon-default:trainingexplicit	-0.34 (0.50)
blockholdsOnly:orientationNon-default:testTypeposttestA	-0.54 (0.43)
blocktransitionsOnly:orientationNon-default:testTypeposttestA	-0.84 (0.47)$^{\cdot}$
blockallClearB:orientationNon-default:testTypeposttestA	0.08 (0.50)
blockholdsOnly:orientationNon-default:testTypeposttestB	-0.56 (0.44)
blocktransitionsOnly:orientationNon-default:testTypeposttestB	-0.39 (0.47)
blockallClearB:orientationNon-default:testTypeposttestB	-0.14 (0.50)
blockholdsOnly:trainingexplicit:testTypeposttestA	-0.67 (0.36)$^{\cdot}$
blocktransitionsOnly:trainingexplicit:testTypeposttestA	-0.31 (0.38)
blockallClearB:trainingexplicit:testTypeposttestA	-0.23 (0.41)
blockholdsOnly:trainingexplicit:testTypeposttestB	-0.50 (0.36)
blocktransitionsOnly:trainingexplicit:testTypeposttestB	-0.28 (0.38)
blockallClearB:trainingexplicit:testTypeposttestB	-0.40 (0.42)
orientationNon-default:trainingexplicit:testTypeposttestA	-0.53 (0.49)
orientationNon-default:trainingexplicit:testTypeposttestB	-0.59 (0.49)
blockholdsOnly:orientationNon-default:trainingexplicit:testTypeposttestA	0.92 (0.59)
blocktransitionsOnly:orientationNon-default:trainingexplicit:testTypeposttestA	1.08 (0.64)$^{\cdot}$
blockallClearB:orientationNon-default:trainingexplicit:testTypeposttestA	0.59 (0.68)
blockholdsOnly:orientationNon-default:trainingexplicit:testTypeposttestB	1.11 (0.59)$^{\cdot}$
blocktransitionsOnly:orientationNon-default:trainingexplicit:testTypeposttestB	0.36 (0.63)
blockallClearB:orientationNon-default:trainingexplicit:testTypeposttestB	0.16 (0.68)
AIC	16574.83
BIC	17009.49
Log Likelihood	-8231.42
Num. obs.	17358
Num. groups: stimWord	94
Num. groups: partsessionid	86
Num. groups: numInBlock	30
Variance: stimWord.(Intercept)	1.79
Variance: partsessionid.(Intercept)	0.98
Variance: partsessionid.testTypeposttestA	2.35
Variance: partsessionid.testTypeposttestB	2.80
Variance: numInBlock.(Intercept)	0.00
Variance: Residual	1.00

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

Table E.2: Mixed effects linear regression coefficient estimates and standard errors.

Appendix F

Fingerspelling comprehension test word list

F.1 Stimulus word list: Training Study I

Items randomized within each condition, practice, clear A, holds-only, transitions-only, clear B.

Practice
face
issue
class
letter

Clear A
part
help
death
method
look
chance
money
place
shop
horse
action
health
space
point
pound

Holds-only
deal
road
room
nation
side
mouth
hair
group
finger
case
game
table
amount
power
town
house
time
others
system
little
fire
chair
animal

window	plant	nature	days	result
state	back	south	level	matter
lord	doubt	water	area	garden
period	sign	least	**Clear B**	door
mother	things	hand	theory	hotel
name	sound	fact	answer	cost
word	effort	terms	miss	land
Transitions-	field	friend	leader	
only	true	trade	rate	
thing	value	change	target	
sort	view	life	order	
minute	while	head	parent	

F.2 Stimulus word list: Training Study II

Items fully randomized across conditions.

face	chance	pound	finger	others
issue	money	deal	case	system
class	place	road	game	little
letter	shop	room	table	fire
part	horse	nation	amount	chair
help	action	side	power	animal
death	health	mouth	town	window
method	space	hair	house	state
look	point	group	time	lord

period	sign	south	head	order
mother	things	water	days	parent
name	sound	least	level	result
word	effort	hand	area	matter
thing	field	fact	theory	garden
sort	true	terms	answer	door
minute	value	friend	miss	hotel
plant	view	trade	leader	cost
back	while	change	rate	land
doubt	nature	life	target	

Appendix G

Fingerspelling comprehension in a blind student

This appendix presents a case study of a blind, hearing student acquiring ASL, called Amelia here. The regular experiment reported in Chapter 5 was not accessible to her, so I created a modified version of the task so she could still complete the course experiment requirement. I do not take these results to be generalizable to other students who access ASL courses through close-vision and/or tactile interpreters, but I also know of no work on this topic so perhaps this case report can prove useful for investigations of this nature in the future.

G.1 Methods

Like the rest of her classmates, Amelia participated in this experiment in exchange for course credit. I implemented several changes to the original design in order to keep her time commitment to the experiment the same as that of other students in her class, and to keep the task as similar as possible. Most notably, Amelia completed only one post-test, instead of two, as each phase in the study took longer for her than they did for sighted participants. Each phase of Amelia's version of the experiment is detailed in the following subsections.

G.1.1 Participant

Amelia is a junior studying Human Development. She accesses ASL course lectures and activities through close-vision interpreters. Sitting very close to Amelia, and in her peripheral vision, interpreters copy what the instructor and other students sign during the class. This means that Amelia has a rather different experience learning ASL in the than that of her sighted peers. As they grow accustomed to their teacher's signing style and see variation when other students sign, Amelia grows accustomed to the interpreters and does not experience variation in input to the same extent. In small group activities, however, Amalia interacts directly with her classmates, rather than through an interpreter. Amelia received an A in her previous ASL course.

G.1.2 Pre-test

Amelia completed the experiment with a live signer since she is unable to see, at least not well enough to discern fingerspelling, on the computer screen. The signer accessed the Qualtrics version of the experiment (to keep her results separate from everyone else's) and mirrored each fingerspelled word. Amelia would then spell back what she'd seen, and the signer would type her answer in the response box on the screen.

In addition to testing the efficacy of the explicit intervention training, one of the crucial factors being tested in the design for sighted participants i the ability ti discriminate fingerspelling in different conditions, namely clear (control), holds only or transitions only. Modifications to the video clips afford this design, which cannot be replicated with a live signer, thus for Amelia, each of the conditions was the same, but her version of the experiment retained the same blocking procedure. Like participants in the main experiment, Amelia has a four-item practice block, followed by 15, 30, 30, and 15 items in each block. The pre-test took approximately one hour, which is double the time it takes most sighted participants to complete it (hence the decision to only give Amelia one post-test).

G.1.3 Explicit training program

Amelia completed the explicit training. Before she began, however, I asked her to describe what strategies she uses for fingerspelling comprehension generally. She articulated three heuristics she follows. First, she looks for what she called "weird" letters. So-called "weird" letters are those with a shape unlike others. The first example she gave was -W-. -W- is a tall letter involving extension of the index, middle, and ring fingers. Amelia is able to tell the difference between this letter and another which also involves extension of three digits, the middle, ring, and pinky fingers (-F-), based on how much space there is between the fingers. That is, she is sensitive to the negative space around extended fingers, which she uses as a cue to letter identification. The second strategy Amelia uses is to look for contrast in handshapes. Are they short or tall, open or closed? She uses this to make the best guesses about which might have been produced since she cannot visually detect the differences between manual letters with similar shape such as letters made with a closed fist including -A-, -S-, -M-, -N-, and -T- (NB: Hanson, 1981, noted that deaf sighted signers often had difficulty distinguishing these manual letters). A final heuristic Amelia uses is identifying the first- and last- letters of each word.

This allows her to narrow the list of possible words and combined with the other strategies, helps her to identify fingerspelled words. For example, consider the word W-I-N-D-O-W. Amelia will identify the first and last letters as “weird" (and tall), then another tall letter in the middle, surrounded by two short letters.

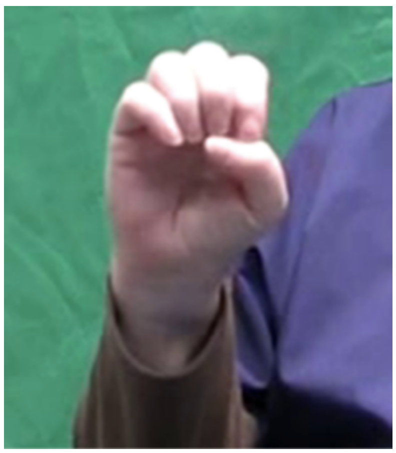
Using the zoom function as she saw fit, Amelia completed the explicit training on my laptop. This allowed her to read the same text as other students during this portion of the training. When still images and videos appeared on a slide, Amelia first viewed them to the best of her ability on the computer screen before asking me to repeat them for her/describe them as needed. For example, consider the images presented on Slide 19, copied here as Figure G.1. After reading the text, if the pictures were not clear to Amelia, I was able to re-produce them, allowing her to see them live and/or examine them tactually.[1] I could also, if she wanted, re-describe what is mentioned in the text. For example, with one hand producing each -E- variant in turn I could indicate with the other hand whether the fingertips contact the thumb.

Unlike the other participants who completed their respective training program away from me, I was able to watch Amelia go through each of the slides. As she did so, I observed her producing letters and fingerspelled words shown as part of the training program, just as she was instructed to do. This suggests that that other participants also interacted with the training instead of viewing it passively.

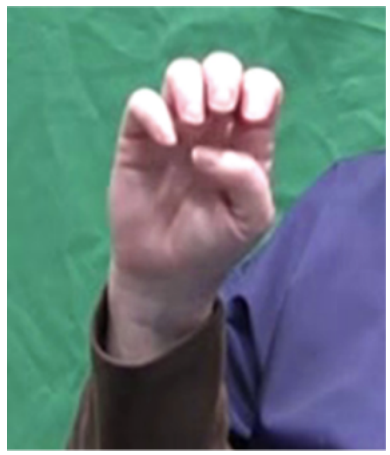
G.1.4 Post-test

The post-test was administered in the same fashion as the pre-test. After the signer viewed a fingerspelled token, it was signed live for Amelia, who them repeated the

[1]Amelia rarely used Tactile ASL but had a basic familiarity with it.



This production of -E- is known as closed because the index, middle, and maybe also ring finger make contact with the thumb.



This production of -E- is known as open because the none of the fingers make contact with the thumb.

Figure G.1: Replication of slide 19 from the explicit training, which draws learners' attention to variation in productions of the letter -E-.

word back to the signer, who then typed it in the answer box, prompting the experiment to present the next item.

G.2 Results

A priori, there is no reason to suspect that Amelia's performance would vary block to block since each of hers is the same. It is also difficult to predict how useful the training might be for at least two reasons. First, the training was not designed with blind learners in mind and second, Amelia already seems to be using cues students are taught to attend to in the explicit training (like the shape of the word). Also, again, it is not clear that the results of this case study are in any way generalizable to other blind adults acquiring ASL. Nevertheless, results from Amelia's pre- and post-tests were calculated in three ways. I used the strict and envelope approaches as Schwarz (2000) did. To be counted as correct in the envelope approach, the response had to have the same number of letters as the target and be of the same shape (short, tall, extra short, letters). Finally, based on Amelia's indication of using the first- and last-letters of words to help identify them, I evaluated results based on whether the first and last letters matched the target. These didn't have to have the same total number of letters. Amelia's results are presented in Table G.1.

In general, the results from all approaches show improvement from pre- to post-test. They also indicate that performance was better when responses are evaluated with the envelope approach as compared to the strict approach and better still with the first/last approach, reaching ceiling in the post test. The potential implications of these findings are discussed below.

	Strict approach		Envelope approach		First/Last approach	
Block	*Pre-test*	*Post-test*	*Pre-test*	*Post-test*	*Pre-test*	*Post-test*
Practice	100%	100%	100%	100%	100%	100%
Block 1	67%	60%	73%	73%	93%	87%
Block 2	76%	90%	83%	90%	93%	97%
Block 3	50%	59%	57%	66%	83%	93%
Block 4	53%	73%	60%	73%	73%	93%
Total	**66%**	**77%**	**73%**	**81%**	**91%**	**98%**

Table G.1: Results from Amelia's pre- and post-tests calculated with three different approaches.

G.3 Discussion

The results presented above show that Amelia improved from pre- to post-test, regardless of how results were calculated. It's unclear if this improvement was directly a result of the training however, as it appears Amelia was already using different cues to understand fingerspelling than sighted learners. Alternative explanations for the improvement as well as other observations about Amelia's participation in this experiment.

Several interesting trends emerged during Amelia's testing sessions, which were impossible to observe with other participants since they took their tests privately. These were:

1. More errors as the experiment went on (more pronounced in the pre-test)

2. Asking for repetition of fingerspelled tokens

3. Types of errors evidenced

During the pre-test practice, and first and second blocks, Amelia answered a fairly high percentage of items correctly, and only viewed each once (recall that stuents were allowed to see each item at most two times). In blocks 3 and 4, Amelia asked for both repetitions of the fingerspelled word and made more errors. It is possible this was due to fatigue. Like other students, she was offered breaks between blocks, but did not take them. In the post-test, she performed much better overall but she also opted for short breaks in between blocks. It's impossible to know whether her improved performance is the result of less fatigue as the experiment wore on, or whether the training was helpful for improving her comprehension skills.

More interesting for the present experiment were the types of errors Amelia made throughout. Many of them were consistent with a movement envelope analysis, which is consistent wither the strategy she explained about looking for "weird" letters. It seems that she is sensitive to changes in overall shape of fingerspelled utterances and uses that to her advantage, presumably because she is unable to see the fine-grained detail of distinct hand configurations that sighted signers can make use of. Examples of the types of errors made on the pre- and post-test are presented in Table G.2. Also, for items on which she was less confident, Amelia would fingerspell to herself to try to make something have the same movement contour as the target item. Once her own productions matched, she reported her answer, whether right or wrong.

The results of this case study suggest that Amelia makes use of different cues in fingerspelling than her sighted classmates. One of the cues she articulated to be the most helpful for her is the very cue that her classmates seem to either ignore, or not weight heavily enough. The goal of the explicit training is to teach these students how to re-weight cues most relevant for successful fingerspelling comprehension. While Amelia improved from pre- to post-test, there are alternative explanations for the

Target word	*Amelia's response*
L-O-R-D	L-A-R-D
C-H-A-I-R	C-L-E-A-R
M-O-T-H-E-R	M-A-T-T-E-R
E-F-F-O-R-T	E-F-F-E-C-T
B-A-C-K	B-A-N-K
S-P-A-C-E	S-P-O-K-E
P-O-I-N-T	P-A-I-N-T
R-O-O-M	R-O-S-E
T-R-A-D-E	T-R-A-C-E

Table G.2: Errors consistent with an envelope approach.

improvement that make it impossible to determine whether the training was the catalyst to her improvement.

Appendix H

Video URLs

Chapter 1

- Figure 1.2

  Items (a)-(d), go to this website and type the sign's English translation equivalent then click on the correct country's flag: `https://www.spreadthesign.com`.

  B-U-T: `http://www.handspeak.com/word/search/index.php?id=290`

Chapter 3

- Figure 3.3 S-O-R-T

  Clear (control): `https://vimeo.com/155694173`

  Holds only: `https://vimeo.com/155694172`

  Transitions only: `https://vimeo.com/155694171`

- Figure 3.5, variation in -E-

  P-O-O-L-E (note the final fingerspelled letter): `https://vimeo.com/155734420`.

The source video for this clip is available at https://m.youtube.com/watch?v=KY4b_nDoShA&feature=youtu.be.

- Figure 3.8 D-I-N-O-S-A-U-R

  (a) https://vimeo.com/155734409

  (b) https://vimeo.com/155734411

  (c) https://vimeo.com/155734423

  (d) https://vimeo.com/155734415

- Figure 3.9 J-O-U-R-N-E-Y

  Full clip: https://vimeo.com/155734407

  Second mention only: https://vimeo.com/155734410

  Source video from http://aslized.org/journal/ei/.

- Figure 3.11 H-E-A-D-L-I-G-H-T

  https://vimeo.com/155734424

- Figure 3.12 T-E-A-C-H-E-R

  https://vimeo.com/155734419 (produced by a different signer than the one pictured, but the relevant features of the -E- productions are the same)

Chapter 4

- §4.2.3

  F-A-C-E (no masking) https://vimeo.com/155538233

  P-A-R-T (no masking) https://vimeo.com/155538237

  F-A-C-E (holds only) https://vimeo.com/155538232

  P-A-R-T (holds only) https://vimeo.com/155538238

F-A-C-E (transitions only) https://vimeo.com/155538235

P-A-R-T (transitions only)https://vimeo.com/155538236

Chapter 5

- Figure 5.1

  Shibboleth test question video sample https://vimeo.com/155570264

- §5.2.3

  F-A-C-E (no masking) https://vimeo.com/155538233

  P-A-R-T (no masking) https://vimeo.com/155538237

  F-A-C-E (holds only) https://vimeo.com/155538232

  P-A-R-T (holds only) https://vimeo.com/155538238

  F-A-C-E (transitions only) https://vimeo.com/155538235

  P-A-R-T (transitions only)https://vimeo.com/155538236

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